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CHANGE IN THE DISTRIBUTION OF THE INDIGENOUS GRASS *POA LITOROSA* ON SUB-ANTARCTIC MACQUARIE ISLAND FOLLOWING THE ERADICATION OF RABBITS

by Laura K. Williams, Chris Howard and Jenny Scott

(with five text-figures and two plates)

Williams, L.K., Howard, C. & Scott, J. 2016 (15:xii) Change in the distribution of the indigenous grass *Poa litorosa* on sub-Antarctic Macquarie Island following the eradication of rabbits. *Papers and Proceedings of the Royal Society of Tasmania* 150(2): 1–8. ISSN 0080-4703. Agronomy and Soil Science, University of New England/ Australian Antarctic Division 203 Channel Highway, Kingston, Tas 7050 (LKW*), Tasmanian Parks and Wildlife Service, GPO Box 44 Hobart, Tasmania 7001, Australia (CH); Geography & Environmental Studies, School of Land & Food, University of Tasmania, Sandy Bay, Tasmania 7001, Australia (JS). *Author for correspondence. Email: laura.williams20@gmail.com

The recent eradication of rabbits, rats and mice from Macquarie Island has resulted in unprecedented changes to the vegetation. One unforeseen outcome is the expansion in the known distribution of the indigenous grass, *Poa litorosa* (L.) which was known from only four restricted populations on Macquarie Island prior to 2014. An increase in abundance of *P. litorosa* was observed in 2014 and so we undertook surveys to document changes in the known distribution of the species and established fixed transects in the new and previously-recorded populations to monitor future changes. Monitoring of an exclosure and control plot over a 24-year period gave insights into past effects of rabbit grazing on the species. Our surveys documented a dramatic increase in the known distribution of the species. Existing populations have expanded and new populations have been recorded. Monitoring of the exclosure and control plot revealed suppression of *P. litorosa* plants in control plots in comparison to fenced plots during peak rabbit numbers, and so we attribute the population expansion to the recent eradication of rabbits and subsequent release of grazing pressure. This research contributes to the increasing bank of knowledge of changes occurring on Macquarie Island post-eradication and highlights the importance of monitoring to detect unforeseen changes.
Key Words: vegetation change, expansion, native species, grazing recovery, monitoring, *Poa litorosa*, Macquarie Island, rabbits, rodents.

INTRODUCTION

Macquarie Island, in the Australian sub-Antarctic, has recently been the focus of one of the largest integrated pest eradication programs to date, with all rats, rabbits and mice eradicated from the island in 2014 (Terauds *et al.* 2014). The European Rabbit (*Oryctolagus cuniculus* Linnaeus, 1758) had a catastrophic impact on the island's natural environment (Taylor 1955, Costin & Moore 1960), causing local and landscape-scale damage. Tall herbfields and tussock grasslands were converted to short grazed lawns or bare ground by selective grazing (Copson & Whinam 2001, Scott & Kirkpatrick 2008, 2013, Bergstrom *et al.* 2009). The tall tussock and mega-herb vegetation provides important habitat for nesting seabirds and invertebrates and appears to reduce the incidence of land slippage and erosion (Scott unpubl. data, Bergstrom *et al.* 2009, Shaw *et al.* 2011, Springer 2011).

As a result of these impacts, the Macquarie Island Pest Eradication Project (MIPEP) was initiated by the Tasmanian Parks and Wildlife Service in 2007, and by July 2011 the rabbit population had been effectively reduced to zero. Extensive hunting and search efforts continued until complete eradication of rats, rabbits and mice was declared a success in 2014 (Terauds *et al.* 2014). Following rabbit eradication, changes to the vegetation were predicted to occur (Copson & Whinam 2001) and, indeed, vegetation recovery and changing vegetation dynamics have already been observed (Scott & Kirkpatrick 2013, Shaw *et al.* 2011, Whinam *et al.* 2014). One predicted outcome of the release of grazing pressure by rabbits is the expansion of some species and the reduction of others (Copson & Whinam 2001). A lack of historical data from the period prior to rabbit establishment (Whinam *et al.* 2014) together with ongoing climate change (Brothers & Bone 2008, Adams 2009) make predictions about a new post-grazing equilibrium state of the vegetation uncertain. It is therefore essential to establish baseline data now, at the start of this new phase for Macquarie Island.

Poa litorosa Cheeseman, a tall tussock grass, was first recorded on Macquarie Island in 1984 and, until recently, was known from only four small populations (Bergstrom *et al.* 2006). Under heavy grazing, *P. litorosa* is difficult to distinguish from other grass species, particularly *Festuca contracta* Kirk (Bergstrom *et al.* 2006). Over the summer of 2013/14, it was noted in several new locations. This paper describes the distribution, abundance and apparent spread of *P. litorosa* on Macquarie Island in the absence of rabbit grazing and provides baseline data for measurement of future change in its distribution and abundance. In addition, we present 24 years of monitoring data on fixed transects in an exclosure plot and adjacent control plot which show the effects of past rabbit grazing on *P. litorosa*.

Study site

Sub-Antarctic Macquarie Island (54°30'S, 158°57'E) is located in the Southern Ocean approximately 1500 km

southeast of Tasmania. The climate is cool, wet and windy. Mean temperatures of the coolest and warmest months range between 3°C and 7°C, mean annual precipitation is around 950 mm and winds are predominantly strong and west to northwesterly (Pendlebury & Barnes-Keoghan 2007). Analysis of changing climate patterns indicates that precipitation and wind speeds are increasing, consistent with an increase in cyclonic weather events. At the same time an increase in atmospheric dryness, along with the increase in wind speeds, may be contributing to drying of the island's surface (Adams 2009).

The flora of Macquarie Island is dominated by grasses, herbs and bryophytes with trees and shrubs completely absent (Selkirk *et al.* 1990). Forty-two indigenous and seven exotic vascular species have been recorded (de Salas & Baker 2015). The island is considered high conservation value due to its abundance of wildlife and unique geology. It is a nature reserve, UNESCO biosphere reserve and World Heritage area (Carmichael 2007, de Villiers *et al.* 2006).

Poa litorosa

Poa litorosa is a tall, wiry tussock abundant on the cold temperate New Zealand shelf islands of the Auckland Island group, Campbell Island and Antipodes (Du Puy *et al.* 1993, Frenot *et al.* 2005). On Campbell Island *P. litorosa* grows most vigorously on sites with enhanced fertility such as coastal areas, swamp flushes and near wildlife colonies, while in upland areas plants are commonly smaller (Meurk *et al.* 1994). *P. litorosa* is also present on Macquarie Island, the only sub-Antarctic island on which it is found (Bergstrom *et al.* 2006), and patterns of growth appear similar to those on Campbell Island. The species was first observed on Macquarie Island by G. Copson in 1983 (P. Turner pers. comm.) and recorded by Seppelt *et al.* in 1984. Between 1983 and 1985 four populations of *P. litorosa* were documented, the largest in the north at Handspike Point near sea-level and three small higher-altitude populations at Caroline Cove Amphitheatre, Caroline Creek and Hill 291 on the southern end of the island (Bergstrom *et al.* 2006) (fig. 1). In the early 1950s B.W. Taylor identified a population of large tussocks at Handspike Point as *Festuca erecta* d'Urv. (*contracta*) which was likely to have been a misidentification of *P. litorosa* (Taylor 1955, Bergstrom *et al.* 2006). Between the 1980s and 2003 various observations were made of the four populations by Bergstrom *et al.* (2006).

METHODS

Documentation of *Poa litorosa* distribution

In February 2014, we observed that *P. litorosa* in areas immediately adjacent to the rabbit grazing exclosure at the Caroline Cove Amphitheatre exhibited a general increase in size, vigour and extent. A thorough distribution survey could not be completed at the time due to inclement weather. During periods of more favourable weather and so improved visibility during March–June 2014, thorough searches were undertaken. Walking line transects were made 15–20 m apart where topography allowed, around the three known southern populations of *P. litorosa* and in all short grassland communities south of latitude 54°44'S (fig. 1). The location of any clumps of *P. litorosa* were recorded with a hand-held GPS unit and the number of plants and presence/absence of seed heads noted. Data were uploaded to the Natural Values Atlas database managed by the Department of Primary Industries, Parks, Water and the Environment, Tasmania.

In March 2014 the Handspike Point *P. litorosa* population was inspected and a brief visual comparison was made with the 2006 map of its extent in Bergstrom *et al.* (2006). Several photos were re-taken from photo-monitoring points set up at the southwest edge of the population in February 2009 (J. Scott), 1–2 years before rabbit eradication.

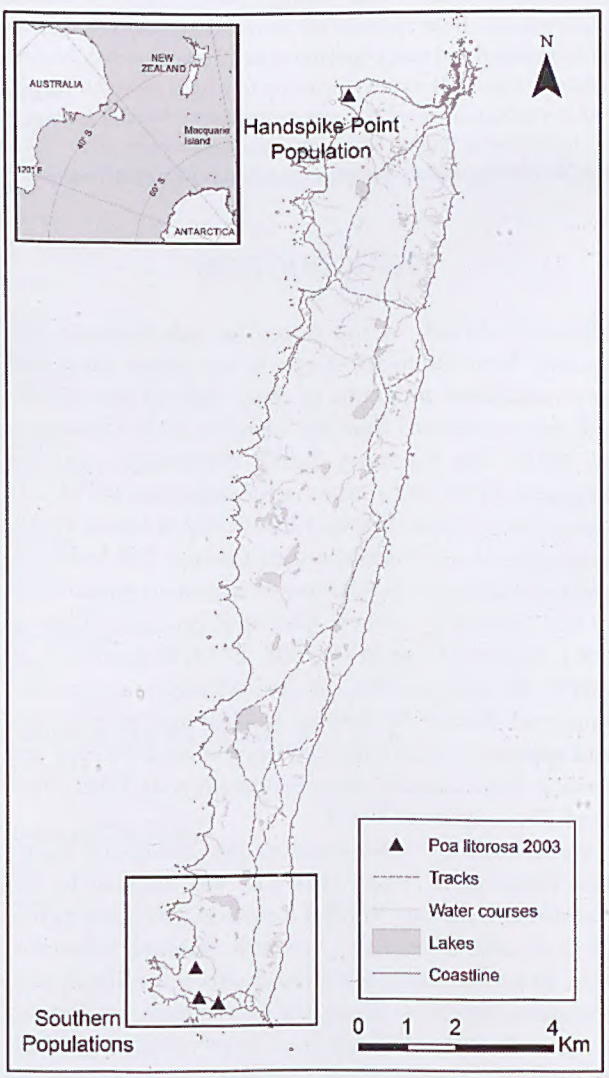

FIG. 1 — Extent of the area in the south of Macquarie Island searched for the presence of *Poa litorosa* (indicated by black box), south of latitude 54°44'S. Black triangles indicate *Poa litorosa* populations recorded prior to 2014.

Establishment of fixed transects for future monitoring and quantification of foliage cover

During January–June 2014 fixed transects were established at Caroline Creek, Carrick Bay and two sites within the Caroline Cove Amphitheatre population (Caroline Cove Amphitheatre 1 and 2) to enable monitoring of future changes in distribution and abundance of *P. litorosa*. A line transect method was used, as presented in Cloud (2009). The centre of the *P. litorosa* population was marked with a small wooden peg and eight 30 m-long transects run out from the centre point at 0, 45, 90, 135, 180, 225, 270 and 315° (fig. 2). The distances at which *P. litorosa* intersected the transect was recorded (i.e., 5–8 cm). A photograph looking down the transect away from the centre peg was taken. Elevation, aspect, latitude and longitude were recorded with a hand-held GPS.

Documentation of grazing pressure along fixed transects, Caroline Cove Amphitheatre population

In 1990 a 5 × 5 m fenced exclosure and an adjacent 5 × 5 m control plot were erected around part of the Caroline Cove Amphitheatre population to protect the plants from rabbit grazing (Bergstrom *et al.* 2006). Over the next 24 years to 2015, line intercept (percentage cover) and plant height data were collected at irregular intervals (1990, 1991, 1995, 2003, 2015) along four fixed 5-m transects, two each in the exclosure and control plots. The distances at which *P. litorosa* intersected the transect and the maximum height of each clump along the transect was recorded and the percentage of each clump which showed signs of rabbit damage (grazed shoots) was visually estimated. Fixed-point photographs were taken each time the measurements were made.

Data analysis

GPS locations of *P. litorosa* populations were imported into ESRI® ArcMap™ 10.0 and expressed as UTM grid coordinates based on the WGS 1984 Datum. The mean percentage cover of *P. litorosa* at each site was determined by calculating the percentage of the transect length that was intercepted by *P. litorosa* and averaging across all eight transects. Statistical analyses were carried out using R version 3.1.1. Results were analysed using analysis of variance (ANOVA). Variances were checked by plotting residual versus fitted values to confirm the homogeneity of the data and normality was checked by quantile-quantile comparison plots. Significant means were separated using Tukey's highest significant difference test.

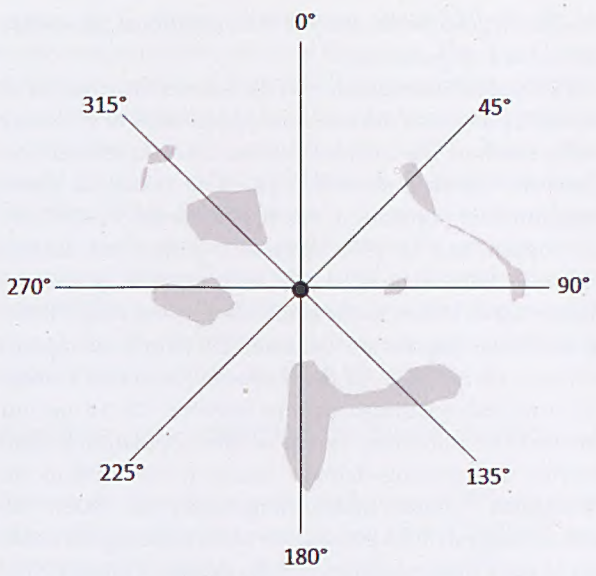

FIG. 2 — Schematic diagram of method used to survey *Poa litorosa* cover, showing angles of line transects from the centre point of the population. Grey areas depict *P. litorosa*.

RESULTS AND DISCUSSION

Poa litorosa distribution (fig. 3)

In February 2014, it was noted that the growth and abundance of *P. litorosa* had increased around the exclosure at the Caroline Creek Amphitheatre population, and plants were larger and of a size not seen since prior to the increase in the rabbit population of the 1990s (J. Scott unpubl. data). This led to further surveys of the distribution of *P. litorosa* which identified an increase in the known distribution of *P. litorosa* around the three previously documented southern

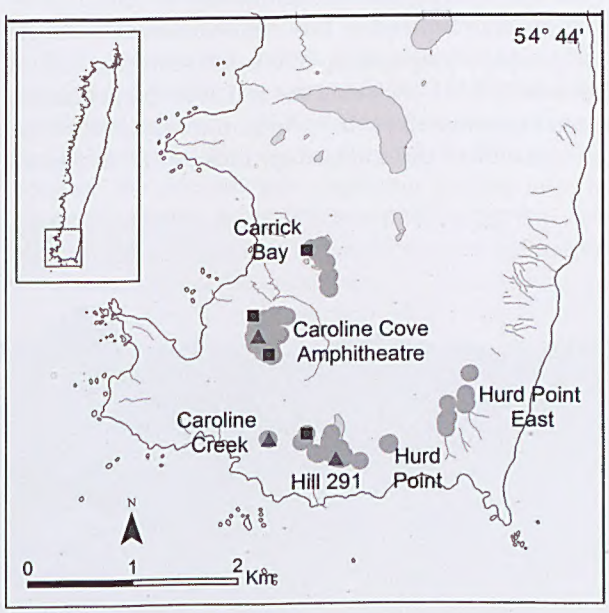

FIG. 3 — Distribution of *Poa litorosa* on Macquarie Island in 2003 (dark grey triangles) and 2014 (light grey circles). Monitoring sites established in 2014 are indicated by black squares.

populations and the discovery of three additional, previously unrecorded, populations.

We observed an expansion in the known distribution of the three previously documented populations of *P. litorosa* in the south of the island, Caroline Cove Amphitheatre, Caroline Creek and Hill 291. The Caroline Cove Amphitheatre population was first recorded in 1983 by G. Copson, and in 1991 consisted of scattered clumps within a 2500 m² area at 160 m a.s.l. with occasional clumps up to 150 m to the south (Bergstrom *et al.* 2006). In 2003 the population consisted of numerous clumps within a 10 m radius of the enclosure, scattered clumps to 20 m and occasional clumps between 20–38 m, but this was the minimum extent of the population as bad weather and grazing damage meant it was difficult to distinguish *P. litorosa* plants (Bergstrom *et al.* 2006). The authors suggested the population was increasing but could not make a firm assessment of the degree of change. The population had never been observed flowering (Bergstrom *et al.* 2006). Our survey in 2014 documented *P. litorosa* plants at a distance of 50 m away from the exclosure. Many hundreds of individuals and small clumps were detected throughout the whole amphitheatre, to a distance of around 300 m from the exclosures and extending over an area of around 22 000 m². Several plants were observed flowering.

The Caroline Creek population was first recorded in November 1983 by G. Copson and consisted of two small tussocks at approximately 180 m a.s.l. In August 1990 the population consisted of four small tussocks, ranging from 0.5 × 0.5 m to 0.3 × 0.7 m in diameter, growing 5–10 m apart along the edge of the creek, but by February 2003 the population had been reduced to one small, rabbit-grazed patch 0.1–0.15 m in diameter (Bergstrom *et al.* 2006). Our survey in 2014 documented around 60 plants covering an area of around 300 m². None was observed flowering.

The Hill 291 population was initially documented by G. Copson in September 1984 and consisted of a single clump along a ridgeline in feldmark/herbfield at 220 m a.s.l. near Hill 291. Between 1984 and 2003 this population was not investigated further (Bergstrom *et al.* 2006). Our surveys in 2014 documented an increase in the known distribution of this population around Hill 291 and a scattering of *P. litorosa* tussocks halfway up the eastern and western banks surrounding Lake Ainsworth which had not been previously recorded. The population consisted of around 200 plants spanning an area of around 18 000 m² with clumps up to 30 m² in size. Plants had a maximum height of 40–50 cm, although most were much smaller, and no plants were observed flowering. Some of these tussocks were seen in 2009 on the high western banks of Lake Ainsworth as part of a photo-monitoring point, but it was concluded at the time that it was *P. foliosa* regrowth without closer observation (J. Scott unpubl. data).

We documented little change in the known distribution and abundance of *P. litorosa* at Handspike Point. This population was first recorded in the 1950s (Taylor 1955) when it was documented incorrectly as *Festuca erecta* (now *contracta)* and described as a dozen or so very scattered tussocks, 0.8–0.9 m tall × 0.9 m wide. In 2003, the population was scattered over a 4 800 m² area at 10–15 m a.s.l., and was characterised by large, tall tussocks (1.2 m tall × 1.0 m wide), many of which were flowering abundantly (Bergstrom *et al.* 2006). When visually inspected in February 2014, distribution boundaries mapped in 2003 by Bergstrom *et al.* (2006) did not appear to have changed significantly and photo retakes taken at several photo-monitoring points set up in 2009 showed little change between 2009 and 2014 at the southern boundary of the site. The 2009 photo (pl.1a) indicates signs of light grazing, while the 2014 photo (pl. 1b) shows slightly denser and higher tussock growth. Some plants were observed flowering. In 2014 many of the tussocks seemed to have expanded, filling inter-tussock spaces evident in 2009, as well as being larger and denser.

Our surveys also detected three previously unrecorded populations of *P. litorosa* at Carrick Bay, Hurd Point and Hurd Point East in the south of the island. The Carrick Bay population was detected en route to Cape Star in a small drainage line on the lower plateau immediately east of Cape Star at an elevation of 200–280 m a.s.l. This population consisted of many hundreds of scattered individuals and small clumps across an area of 44 900 m², with some

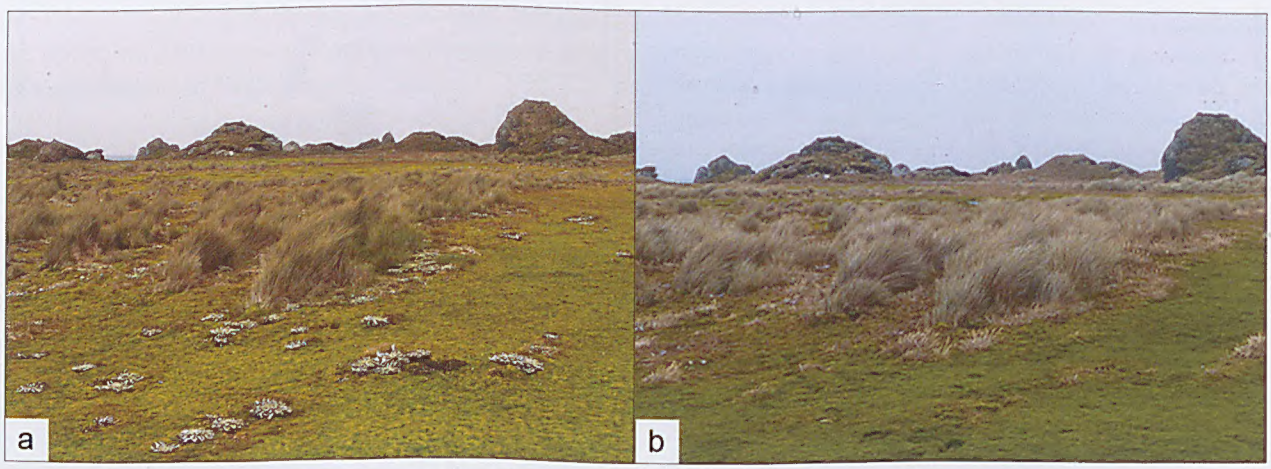

PLATE 1 — *Poa litorosa* at Handspike Point in 2009 (a) and *P. litorosa* at Handspike Point in 2014 (b), taken from the same photopoint.

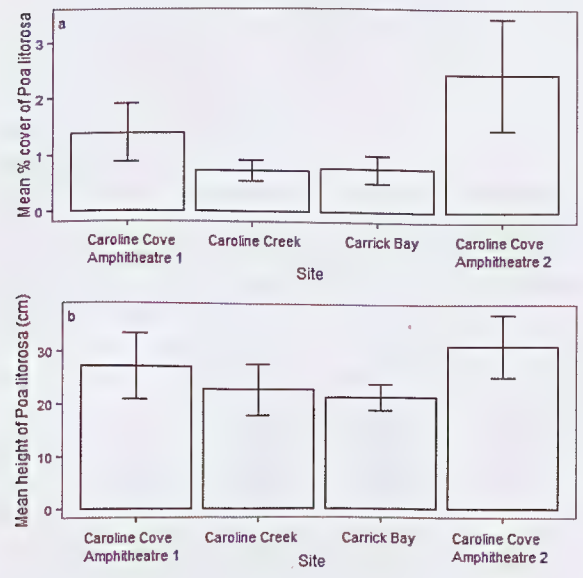

FIG. 4 —Mean percentage cover of *Poa litorosa* at four sites on Macquarie Island in 2014, n = 8 (a); and mean height of *P. litorosa* at four sites on Macquarie Island in 2014 (b), measured along 8 x 30 m line transects at each site. Error bars represent 95 % confidence intervals.

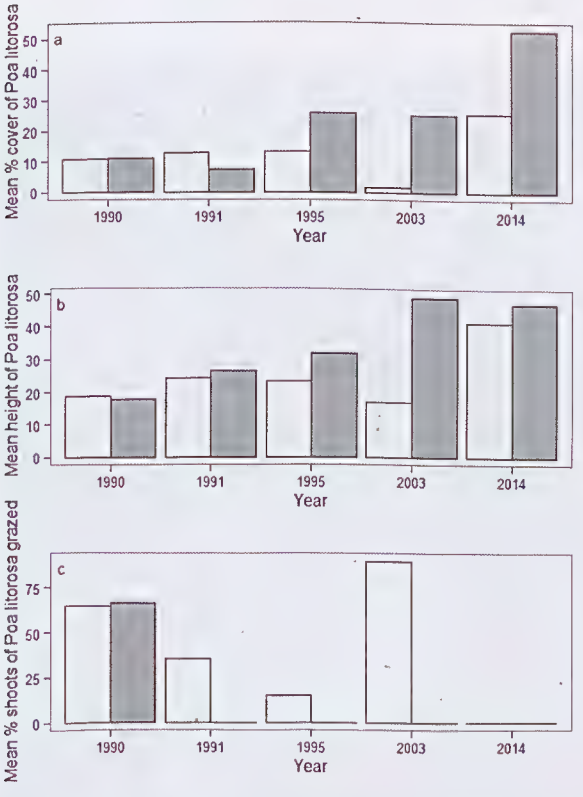

FIG. 5 — Mean percentage cover (a); height (b) and percentage of shoots grazed (c) of *Poa litorosa* in control (unfilled bars) and exclosure (filled bars) plots at Caroline Cove Amphitheatre over a 24-year period, measured along 4 x 5-m fixed line transects.

clumps up to 40 m². Plants were around 20–30 cm in height and some were observed flowering. The Hurd Point population consists of around 270 plants growing along the top of the escarpment below the ridgeline at an elevation of 230–260 m with a southeasterly aspect. Plants were around 20–25 cm in height. None was observed flowering. The Hurd Point East population consisted of five plants growing at the top of the south-facing escarpment at an elevation of 240 m. Plants were small in size and none was observed flowering. No new populations were documented around the Handspike population or opportunistically visited locations in the north of the island.

Baseline data collection for future monitoring

Data on the abundance and distribution of *P. litorosa* was collected along fixed transects at four sites (Caroline Cove Amphitheatre 1 and 2, Caroline Creek, Carrick Bay). These data describe the proportion of each of eight transects per site intersected by *P. litorosa* and the height of each clump of *P. litorosa* intersecting the transect. This information provides a detailed baseline dataset on which future monitoring of *P. litorosa* can be based and is available from the Natural Values Atlas database (Department of Primary Industries, Parks, Water and the Environment, Tasmania) and will be available at the Australian Antarctic Data Centre. These data were used to determine the mean percentage cover of *P. litorosa* at each site and ranged from 0.7 to 2.4% cover (fig. 4). The mean height of *P. litorosa* plants was around 25 cm at each of these four sites (fig. 4).

Changes in the Caroline Cove Amphitheatre exclosure and control plot over time in response to grazing pressure

There were no statistical differences in the mean percentage cover, height and percentage of shoots grazed between the exclosure and control plot at each time period ($P \geq 0.05$). This was due to a low number of replicates and high variability in the data as this experiment was established quickly and *ad-hoc* in 1990 by scientists concerned about the survivorship of *P. litorosa* at the peak of rabbit grazing. However, the data still give important insights into the impacts of rabbit grazing on *P. litorosa*. When the plots were first established, there was little difference in the heights of *P. litorosa* shoots, the abundance of *P. litorosa* along the transects, and the percentage of *P. litorosa* shoots which were grazed (fig. 5), between the exclosure and control plot. Within the exclosure the mean maximum height of ungrazed *P. litorosa* shoots increased over the 13-year period until 2003, with a large increase between 1995 and 2003, and showed a slight decrease 11 years later in 2014 (possibly an artefact of a different researcher doing the later measurements). In the control plot the mean maximum height of shoots changed little until 2003, indicating a regular overall pattern of grazing of the species with shoots being eaten down to 12–15 cm and never reaching above 24 cm (fig. 5). The increase in height of *P. litorosa* in the control plot during the first six months, between the initial

measurement in August 1990 and the second measurement six months later in February 1991, is likely to represent spring and summer growth.

Percentage cover of the transect lines by *P. litorosa* increased within the exclosure plot over the 24-year period, although there was some fluctuation within this period. Percentage cover increased for the first five years, remained stable for the next eight years and had increased greatly by 2014. The mean percentage cover of *P. litorosa* in the control plot remained relatively stable for the first five years to 1995 and then decreased to 2003, exhibiting an inverse pattern to the changes in cover of *P. litorosa* in the exclosure plot, then increased greatly by 2014. The mean percentage of *P. litorosa* shoots that were grazed within the exclosure plot declined to zero in the first six months of the study period, indicating the success of the fencing at excluding rabbits. Within the control plot, the mean percentage of *P. litorosa* shoots that were grazed declined over the first five years, and then increased over the next eight years until 2003. This is likely to reflect fluctuations in rabbit numbers in the Caroline Cove Amphitheatre, with heavier grazing pressure during the first, second and fourth measurement periods (1990, 1991, 2003) than during the third (1995). This follows the general trend in rabbit numbers for the island as a whole over this period (Terauds *et al.* 2014). No grazing was observed in 2014 as grazing pressure had ceased several years before this measurement.

The photo-point photographs of the exclosure and control plots over the 24 years confirm the trends discussed above (pl. 2). There was an increase in growth and extent of *P. litorosa* in a control plot over the first five years to February 1995, compared to the previous measurement in February 1991. A comparison of plate 2a, b and c shows a decrease in growth and extent of *P. litorosa* in the control plot over the 12.5 years to February 2003 and the steady increase in height of *P. litorosa* in the exclosure over the 12.5 years. By February 2003 the exclosure plants had started to develop into distinct small tussocks (pl. 2c), away from the uneven discontinuous turf habit displayed during previous measurements and still evident in the control (pl. 2a, b). By 2014, growth and extent of *P. litorosa* had increased markedly in both exclosure and control (pl. 2d).

CONCLUSIONS

A substantial increase in the recorded distribution of *P. litorosa* has been seen between 2003 and 2014 and we attribute this to a release of grazing pressure following the eradication of rabbits. The three previously known southern populations were first detected following the post-myxomatosis decline in rabbit numbers in the early 1980s when grazing pressure was reduced (Terauds *et al.* 2014). Indeed, *P. litorosa* has been found to decline in the presence

PLATE 2— Changes in the abundance and height of *Poa litorosa* between 1991 (a), 1995 (b), 2003 (c) and 2014 (d) in a control plot (left side of fence line) and in an exclosure plot (right side of fence line). Note fence had been removed by 2014 as rabbits had been eradicated, although corner posts remain for reference.

of grazing and increase when grazing ceased on several of the New Zealand shelf islands (Dilks & Wilson 1979, Rudge & Campbell 1977, Taylor 1968, UNESCO 1966). When grazed, *P. litorosa* and *F. contracta* are difficult to tell apart, thus these populations may have been established for some time but were not detected previously due to grazing impacts (Bergstrom *et al.* 2006). For the same reasons, further populations were not detected during this time. Following the eradication of rabbits, the grazing pressure on the vegetation has been completely lifted, allowing plants to grow unrestricted. Given the substantial size of many of the *P. litorosa* plants, it is likely these populations have been present for a long time but have been maintained at undetectable levels by rabbit grazing. The effects of grazing on *P. litorosa* are illustrated in plate 2.

Although we observed dramatic changes in the *P. litorosa* populations in the south of the island, the Handspike Point population differed little between 2003 and 2014. This site has a very different environment to the southern sites, including lower elevation, higher exposure and waterlogged soil. The Handspike Point population, although grazed, appears not to have been as heavily grazed as the southern population (Bergstrom *et al.* 2006) and so has probably been less affected by the release of grazing pressure. Further observations at the described sites will enable future changes in populations of *P. litorosa* to be documented.

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REFERENCES

Adams, N. 2009: Climate trends at Macquarie Island and expectations of future climate change in the sub-Antarctic. *Papers and Proceedings of the Royal Society of Tasmania* **143**: 1–8.

Bergstrom, D.M., Lucieer, A., Kiefer, K., Wasley, J., Belbin, L., Pedersen, T.K., & Chown, S.L. 2009: Indirect effects of invasive species removal devastate World Heritage Island. *Journal of Applied Ecology* **46**: 73–81. doi: 10.1111/j.1365-2664.2008.01601.x

Bergstrom, D.M., Turner, P.A.M., Scott, J., Copson, G. & Shaw, J. 2006: Restricted plant species on sub-Antarctic Macquarie and Heard Islands. *Polar Biology* **29**: 532–539. doi: 10.1007/s00300-005-0085-2

Brothers, N. & Bone, C. 2008: The response of burrow-nesting petrels and other vulnerable bird species to vertebrate pest management and climate change on sub-Antarctic Macquarie Island. *Papers and Proceedings of the Royal Society of Tasmania* **142**: 123–148.

Carmichael, N. 2007: Macquarie Island, its conservation and management. *Papers and Proceedings of the Royal Society of Tasmania* **141**: 11–17.

Cloud, A. (ed.) 2009: *Australian Soil and Land Survey Field Handbook*. CSIRO Publishing, Collingswood, Victoria: 264 pp.

Copson, G. & Whinam, J. 2001: Review of ecological restoration programme on subantarctic Macquarie Island: Pest management progress and future directions. *Ecological Management and Restoration* **2**: 129–138. doi: 10.1046/j.1442-8903.2001.00076.x

Costin, A.B. & Moore, D.M. 1960: The effects of rabbit grazing on the grasslands of Macquarie Island. *Journal of Ecology* **48**: 729–732. doi: 10.2307/2257346

de Salas, M. & Baker, M. 2015: *A Census of the Vascular Plants of Tasmania and Index to the Student's Flora of Tasmania and Flora of Tasmania Online*.Tasmanian Herbarium, Tasmanian Museum and Art Gallery, Hobart, http://www.tmag.tas.gov.au/collections_and_research/tasmanian_herbarium/tasmanian_herbarium_publications (accessed 1 October 2015).

de Villiers, M.S., Cooper, J., Carmichael, N., Glass, J.P., Liddle, G.M., McIvor, E., Micol, T. & Roberts, A. 2006: Conservation management at Southern Ocean islands: towards the development of best-practice guidelines. *Polarforschung* **75**: 113–131. doi: 10.1007/s003000050423

Dilks, P. & Wilson, P. 1979: Feral sheep and cattle and royal albatrosses on Campbell Island; populations trends and habitat changes. *New Zealand Journal of Zoology* **6**: 127–139.

Du Puy, D.J., Telford, I.R.H. & Edgar, E. (eds) 1993: Poaceae., *Flora of Australia, Oceanic Islands*. Australian Government Publishing Service, Canberra: 406 pp.

Frenot, Y., Chown, S.L., Whinam, J., Selkirk, P.M., Convey, P., Skotnicki, M. & Bergstrom, D.M. 2005: Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews* **80**: 4–72. doi: 10.1017/S1464793104006542

Meurk, C., Foggo, M. & Wilson, J. 1994: The vegetation of subantarctic Campbell Island. *New Zealand Journal of Ecology* **18**: 123–168.

Pendlebury, S. & Barnes-Keoghan, I.P. 2007: Climate and climate change in the sub-Antarctic. *Papers and Proceedings of the Royal Society of Tasmania* **141**: 67–81.

Rudge, M. & Campbell, D. 1977: The history and present status of goats on the Auckland Islands (New Zealand subantarctic) in relation to vegetation changes induced by man. *New Zealand Journal of Botany* **15**: 221–253.

Scott, J.J. & Kirkpatrick, J.B. 2008: Rabbits, landslips and vegetation change on the coastal slopes of subantarctic Macquarie Island, 1980–2007: Implications for management. *Polar Biology* **31**: 409-419. doi: 10.1007/s00300-007-0367-y

Scott, J.J. & Kirkpatrick, J.B. 2013: Changes in the cover of plant species associated with climate change and grazing pressure on the Macquarie Island coastal slopes, 1980–2009. *Polar Biology* **36**: 127–136. doi: 10.1007/s00300-012-1243-y

Selkirk, P., Seppelt, R. & Selkirk, D. 1990: *Subantarctic Macquarie Island: Environment and Biology*. Cambridge University Press, Cambridge: 285 pp.

Seppelt, R., Copson, G. & Brown, M. 1984: Vascular flora and vegetation of Macquarie Island. *Tasmanian Naturalist* **78**: 7–12.

Shaw, J.D., Terauds, A. & Bergstrom, D.M. 2011: Rapid commencement of ecosystem recovery following aerial baiting on sub-Antarctic Macquarie Island. *Ecological Management & Restoration* **12**: 241–244. doi: 10.1111/j.1442-8903.2011.00611.x

Springer, K. 2011: Planning processes for eradication of multiple pest species on Macquarie Island – an Australian case study. *In*: Veitch, C.R., Clout, M.N. & Towns, D.R. (eds), *Island Invasives: Eradication and Management*. International Union for Conservation of Nature, Gland: 228–232.

Taylor, B.W. 1955: *The flora, vegetation and soils of Macquarie Island*. Botany, Hobart: 192 pp.

Taylor, R. 1968: Introduced mammals and islands: Priorities for conservation and research. *Proceedings of the New Zealand Ecological Society* **15**: 61–67.

Terauds, A., Doube, J., McKinlay, J. & Springer, K. 2014: Using long-term population trends of an invasive herbivore to quantify the impact of management actions in the sub-Antarctic. *Polar Biology* **37**: 833–843. doi: 10.1007/s00300-014-1485-y

UNESCO. 1966. *Towards a new relationship of man and nature in temperate lands*. Part II of the 10th Technical Meeting of the International Union of the Conservation of Nature, Lucerne. I.U.C.N.

Whinam, J., Fitzgerald, N., Visoiu, M. & Copson, G. 2014: Thirty years of vegetation dynamics in response to a fluctuating rabbit population on sub-Antarctic Macquarie Island. *Ecological Management & Restoration* **15**: 41–51. doi: 10.1111/emr.12076

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DECADAL-SCALE VEGETATION DYNAMICS ABOVE THE ALPINE TREELINE, MOUNT RUFUS, TASMANIA

by Violet Harrison-Day, Bryan Annandale, Jayne Balmer and Jamie B. Kirkpatrick

(with four text-figures, four plates and three tables)

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Alpine areas by definition have summer temperatures too cool to support trees. Concerns have been raised that trees may invade these distinctive habitats where global climate change results in an increase in summer temperatures beyond the threshold limiting tree growth. In 2016, we investigated changes in the treeline and vegetation immediately above it by resampling quadrats and rephotographing from the set points established in the Alpine Treeline Ecotone Monitoring Program on Mount Rufus, Tasmania, in 2006. Within the study area, the only species with the potential to reach a tree height > 3 m is *Eucalyptus coccifera* Hook.f. The height, density, basal diameter and diameter at breast height were recorded for all *E. coccifera* within the study area, together with an estimate of percentage cover of each vascular plant species. No change was found in the location of the treeline over the 10-year period, although *E. coccifera* height and density above the treeline did increase. The vegetation on the north-facing slope shifted to a composition more closely related to the forest below the treeline, while on the south-facing slope forest species reduced in abundance and the vegetation became more dominated by alpine species. Historical aerial photographs suggest that there has been a minor and inconsistent establishment of *E. coccifera* plants at higher altitudes since 1953. The area was burned by bushfire in 1965, making it difficult to separate the effects of putative climate change and recovery after the fire event on vegetation changes, although data from Lake St Clair suggest a local constancy of mean growing season temperatures and rainfall.
Key Words: climate change, fire, subalpine forest, tree growth, tree mortality, *Eucalyptus coccifera*.

INTRODUCTION

Climate change is likely to have long-term effects on alpine ecosystems (Settele *et al.* 2014, Williams *et al.* 2015). The alpine zone, which is characterised by the absence of trees, is located between the alpine treeline and the line of permanent snow and ice. In Tasmania it is also characterised by a rich floristic diversity in which up to 70% of vascular plant species on particular mountains are endemic to Tasmania (Kirkpatrick 1982). The alpine treeline is defined by Paulsen & Körner (2014) as the maximum line of elevation that connects groups of trees growing to a height of 3 m or more. It is distinct from the forest line (timberline), which is the mean maximum line of elevation at which trees form continuous cover (Paulsen & Körner 2014). The alpine treeline forms where temperatures become too low to support tree growth. In Tasmania, trees are often excluded for other environmental reasons, making it difficult to locate the climatic treeline (Kirkpatrick 1982). The position of alpine treelines around the world has been modelled by Paulsen & Körner (2014) as a minimum growing season length of 94 days with all days exceeding a mean air temperature of 0.9°C and a mean air temperature of 6.4°C over the season. In Tasmania, Green & Stein (2015) found that a mean growing season air temperature of 5.85°C predicted the area mapped as alpine by Kirkpatrick (1983). However, this mapped area includes treeless vegetation below the alpine treeline (Kirkpatrick 1983).

Increases in the elevation of alpine treelines are likely to affect alpine ecosystems (Harsch *et al.* 2009, Greenwood & Jump 2014, Hagedorn *et al.* 2014). The conical nature of many mountains with alpine ecosystems may result in the exponential shrinking of available habitat for alpine species as climates warm (Settele *et al.* 2014). Alpine treelines which are diffuse have advanced more than those of abrupt form (Harsch *et al.* 2009), although many alpine treelines have not changed in location, despite changes in climate (Harsch *et al.* 2009). In Australia, the biota of the alpine zone is thought to be particularly susceptible to climate change. Alpine and treeless subalpine areas occupy less than 0.15% of total land area (Costin *et al.* 1979), with areas above the alpine treeline constituting only 0.016% (Green & Stein 2015). Alpine ecosystems occur within narrow altitudinal ranges, and are without a nival zone to provide potential refugia (Williams *et al.* 2015, Pickering *et al.* 2008). Species which are present at only the highest alpine elevation and in high alpine environments, such as snow patches, may be increasingly threatened, with some species and environments already having been assessed as being "endangered" according to IUCN Red List criteria (Pickering *et al.* 2008, Williams *et al.* 2015, Parry *et al.* 2016). In some alpine areas, such as the Snowy Mountains, greater local endemism is found at higher elevations, so increasing temperatures and decreasing snow cover may pose an extinction risk (Pickering *et al.* 2008). Increasing fire frequency and intensity caused by climatic change is also likely to threaten some Tasmanian species (Kirkpatrick & Bridle 2013).

In the Snowy Mountains, alpine species could be at risk of extinction due to lack of refugia and encroachment

by lower-elevation shrubs, herbs and introduced weeds (Pickering *et al.* 2008). Snow patches have declined, potentially threatening their specialised plant communities (Green & Pickering 2009), and changes in snowmelt patterns have been found to affect vegetation growth, with implications for the future composition of plant communities (Venn *et al.* 2011). Venn *et al.* (2012) found that mean species richness has increased on the Snowy Mountain summits. Vegetation compositional changes have varied between higher- and lower-elevation summits (Venn *et al.* 2014) and between burned and unburned sites under experimental warming conditions (Camac *et al.* 2015). In Tasmania, there are no published data on recent vegetation change at and immediately above the alpine treeline, temporal studies having concentrated on recovery from fire (e.g., Kirkpatrick & Dickinson 1984, Kirkpatrick *et al.* 2010), responses to grazing (e.g., Bridle *et al.* 2001, Kirkpatrick & Bridle 2016) and mire and fjaeldmark dynamics (Gibson & Kirkpatrick 1992, Kirkpatrick *et al.* 2002a).

Tasmanian alpine areas differ from those of mainland Australia in their maritime climate, which has led to differing patterns of precipitation, duration of snow cover, species composition and marsupial grazing, and in their histories of fire (Kirkpatrick & Bridle 2013). While mainland alpine areas have vegetation which is able to recover swiftly from burning (Williams *et al.* 2008), Tasmanian alpine areas have a less extensive history of burning, and a higher incidence of fire-sensitive species, leading to long-term changes when burned rather than swift recovery (Kirkpatrick & Bridle 2013).

Eucalyptus coccifera Hook.f., the Snow Peppermint, is endemic to Tasmania where it forms the alpine treeline on most eastern and central mountains (Williams & Potts 1996). It intergrades with *E. nitida* Hook.f., which replaces it on quartzite mountains (Shaw *et al.* 1984). At lower elevations *E. coccifera* typically forms a tall, straight, single-stemmed tree up to 40 m in height. Tree height and leaf size decline with elevation, while glaucousness and lignotuber development increase. It is often of mallee form at the treeline (Pyrke & Kirkpatrick 1994). The above-ground parts of the plant are usually killed by fire, the tree resprouting from the basal lignotuber. As with other eucalypts, seed is stored in woody capsules and is released following fire. The recruitment of this species in the absence of fire has not been studied, but light limitation is not likely to be an impediment to germination and survival in many areas at the treeline and above. Its frequent mixture with much older individuals of more fire-sensitive species also strongly suggests continuous regeneration (Kirkpatrick & Balmer 1991).

The study site is situated in the Tasmanian Wilderness World Heritage Area, listed by UNESCO for the outstanding universal value of both its natural and cultural heritage, including its distinctive alpine ecosystems (UNESCO 2008). This study area is therefore of global relevance, in addition to providing important information at a regional scale and filling a gap in the Australian published literature on treeline change.

Our aim in the present study was to assess vegetation change at an alpine treeline on Mount Rufus, Tasmania, in the period 2006–2016, firstly by examining change in vegetation composition above the treeline, and secondly by assessing any change in the density, heights and diameters of the tree *E. coccifera* in the vegetation above the treeline. We also investigated climatic data recorded at the nearest weather station to determine whether there is any evidence for changes in summer temperatures that may explain observed patterns in vegetation at the treeline. We hypothesised that the vegetation above the treeline is becoming increasingly dominated by forest species, and that the tree species *E. coccifera* is increasing in size and abundance above the treeline.

METHODS

Study area

Mount Rufus lies towards the southern end of the Cradle Mountain – Lake St Clair National Park in central Tasmania (pl. 1). The surface geology is composed of Triassic sandstone of the Upper Parmeener Supergroup. Glacial action has had a strong influence on the topography of the region, with large glaciers having been present on the northern and eastern slopes of the mountain during the Last Glacial Maximum (19 ka BP; Colhoun *et al.* 1996).

The most recent fire on Mt Rufus occurred in 1965 (Styger & Balmer 2009) and completely burned the eastern ridge of the mountain, including all except a few small patches in the study area (pl. 1). Large dead stems of *E. coccifera*, some taller than 20 m, that were killed in the fire, can still be observed standing below the treeline.

The dominant tree species is *E. coccifera*, which forms an abrupt treeline on the upper slopes of the mountain (pl. 2). The occurrence of abrupt treelines in Tasmanian is unusual, with only a few other locations across the state displaying similar sharpness (Kirkpatrick 1982). Above the treeline, the vegetation opens up into alpine heath dominated by *Epacris serpyllifolia* R.Br., *Orites acicularis* (R.Br.) Roem. & Schult., *O. revoluta* R.Br. and *Boronia citriodora* Gunn ex Hook.f., with the occasional isolated *E. coccifera*. Small long-unburned patches are dominated by gymnosperms, including *Microcachrys tetragona* (Hook.) Hook.f.

Monitoring at the site began in 2006 as part of the Alpine Treeline Ecotone Monitoring Program within the Tasmanian Wilderness World Heritage Area (Styger & Balmer 2009) undertaken by the Tasmanian Department of Primary Industries, Parks, Water and Environment. The purpose of this program was to measure site specific ecosystem responses to climate change and to use this information to predict responses at different spatial and temporal scales (Styger & Balmer 2009).

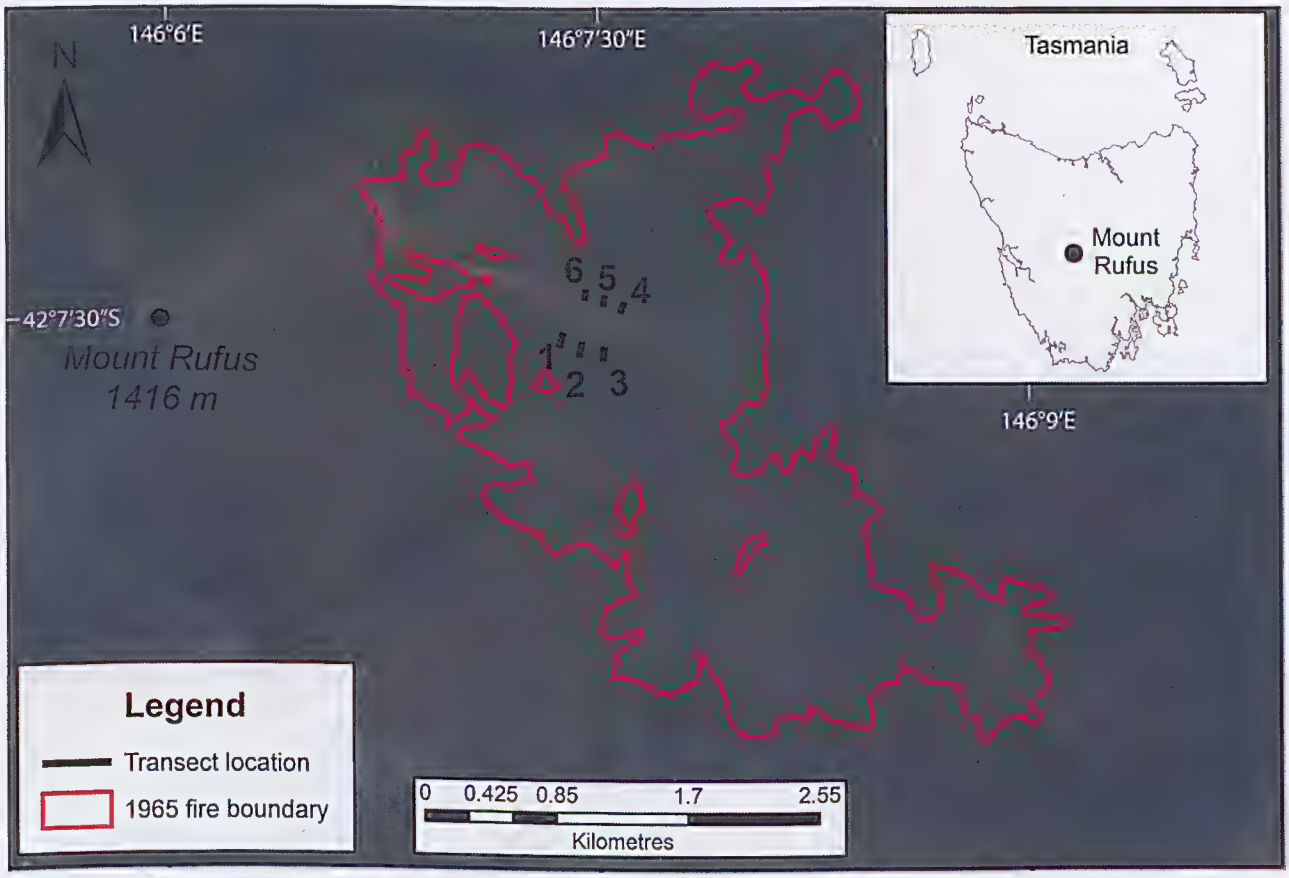

PLATE 1 — Location of transects at the study site on Mount Rufus, with approximate 1965 fire boundary mapped from a 1982 aerial photograph. Grid reference GCS WGS 1984 (Source: DPIPWE and Google Maps).

PLATE 2 — Comparison of an aerial photograph from 1953 and a satellite image from 2015, showing the location of the treeline on Mount Rufus, Tasmania. Note the increase in the number of small *Eucalyptus coccifera* plants on the northern slope (A), and the expansion of a clump of *E. coccifera* on the southern slope (B) between images (Source: DPIPWE and Google Maps).

Field data collection

In 2006, three belt-transects were established on the northern aspect and three on the southern aspect of the Mt Rufus ridge (pl. 1). All six belt-transects included five 10 x 10-m plots above the treeline. Below the treeline the belt-transects varied in length with four comprising the full five 10 x 10-m plots, while two were reduced in length to 20 m and 40 m respectively because of the considerable sampling difficulty arising from the greater slope steepness and vegetation density. In 2016, only the upper and lower alpine quadrats in each belt-transect were resampled for species composition. *Eucalyptus coccifera* stems were resurveyed within all the alpine quadrats.

In each quadrat, vascular plant species cover was estimated as a percentage for each taxon. Those with less than 1% cover were entered as 0.5. The maximum height for each shrub species (cm) was also measured. The position, diameter at base and height, of all observed *E. coccifera* individuals in the alpine plots were recorded. Where possible, the X and Y co-ordinates were used to identify the individual *E. coccifera* trees recorded in 2006. This was not possible, however, where the tree was no longer present, or in plots where too many trees were present in close proximity to each other to accurately identify those originally recorded. All trees found that had not been listed previously were also recorded. If trees were found dead, or with dead wood present above living parts of the tree, this was also noted, and the maximum living height recorded.

Photo points were located at 10 m uphill, and at 10 m to the west, of the 0 and 50 m marks of each of the transects. The photographs were taken at each photo point focusing on a disc suspended 1.4 m above the permanent stake points (at 0 and 50 m on the transect line). Photographs were taken at each of the photographic monitoring points in both 2006 and 2016.

Data analysis

Non-metric multidimensional scaling ordination (NMDS) using the program DECODA (Minchin 1990) was used to ordinate the species cover data for the pool of quadrats at both dates. Uniform random coordinates were used for ten starting configurations in up to four dimensions, with a maximum number of 200 iterations. A solution scaling option of two half changes was selected. Rotational correlation analysis was used to find the best fit between the ordination axes derived from the NMDS and the variables aspect (north and south), date (2006 and 2016), and distance (quadrat number from one at highest elevation to the highest at lowest elevation, treeline between five and six), in three-dimensional space. The axes were shown to be respectively highly correlated with distance from treeline, aspect and date. One way analysis of variance was used to test for the effects that each of aspect, date and distance had on change in floristic composition as indicated by the axis scores. The paired t-test was used to determine the significance of changes in cover of the more abundant species between dates. The relationship between *E. coccifera* height and density change between 2006 and 2016 and change in the "alpineness" of the floristic composition as indicated by the scores on the axis related to distance was tested using linear regression analysis. Minitab 16 (Minitab Inc. 2010) was the primary software used for statistical analysis, unless stated otherwise.

The Kruskal-Wallis H test was used to test the significance of differences in tree height change, and tree density change, between 2006 and 2016, distance (quadrat number) and aspect (north- versus south-facing slopes). The differences between height classes (<50 cm, 50–100 cm and >100 cm) for all trees that were re-identified in 2016 from the 2006 survey (hereafter referred to as paired trees) were tested for any significant change using the Kruskal-Wallis H test. The differences in *E. coccifera* height between 2006 and 2016 was also divided into a second set of height classes (<100 cm and >100 cm), and linear regression used to determine any trend in height change within the two height classes between years. The effect of aspect on paired tree height change between 2006 and 2016 was tested using the Kruskal-Wallis H test. This test was repeated using only trees less than 100 cm in height.

The closest weather station is located at Lake St Clair (42°7'4"S, 146°10'38"E, 742 m asl), with regular temperature and rainfall data being available for the years 1989 onwards. An environmental lapse rate of 0.75°C per 100 m change in elevation for maximum temperature, 0.5°C per 100 m for minimum temperature, and 0.63°C per 100 m for mean daily temperature (Nunez & Colhoun 1986) was used to calculate approximate temperatures at the study site, situated at ~1200 m. Pearson's product moment correlation coefficient was used to determine the linear relationship between time and the daily mean, maximum, and minimum temperatures for the month of January, and total precipitation for the summer and winter months, for the years 1991 to 2015. Total annual precipitation was analysed using the same methods. Data were sourced from the Bureau of Meteorology Climate Data Online in 2016.

RESULTS

At the alpine treeline on Mt Rufus, the mean daily summer temperature (Dec–Feb) was calculated to be 8.9°C. There is a marked seasonality in precipitation at Lake St Clair, with winter receiving a monthly mean of 201.8 mm, while in summer the monthly mean is 104.9 mm. The annual precipitation is 1856.7 mm. The mean is likely to be much higher near the summit of Mt Rufus. Lake St Clair has experienced no systematic change in daily mean ($r = 0.259$, $p = 0.211$), maximum ($r = 0.271$, $p = 0.190$), or minimum ($r = 0.105$, $p = 0.618$) temperature, or precipitation ($r = -0.018$, $p = 0.934$) for January for the 25 years between 1991 and 2015 (fig. 1). Annual precipitation ($r = -0.269$, $p = 0.215$), and the seasonality of precipitation (summer: $r = -0.113$, $p = 0.591$, winter: $r = -0.204$, $p = 0.328$) also showed no trend.

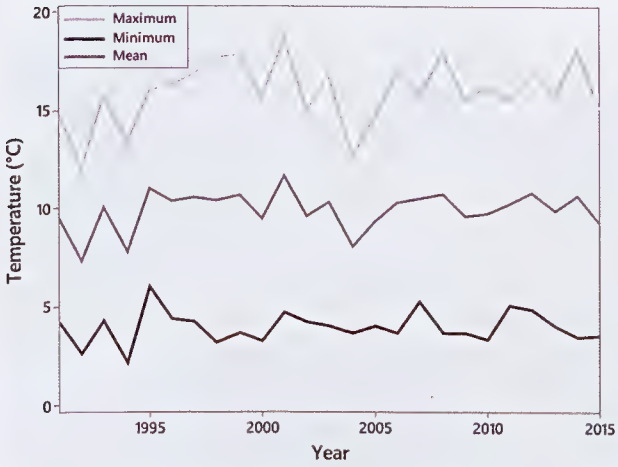

FIG. 1 — Mean daily maximum, minimum and mean temperatures for the month of January (between 1991 and 2015) at the study site on Mount Rufus (~1200 m). Temperatures corrected for altitude from Lake St Clair weather station using an adiabatic lapse rate of 0.75°C/100 m for maximum, 0.5°C/100 m for minimum, and 0.63°C/100 m for mean (Nunez & Colhoun 1986) (Data from Bureau of Meteorology, accessed 2016).

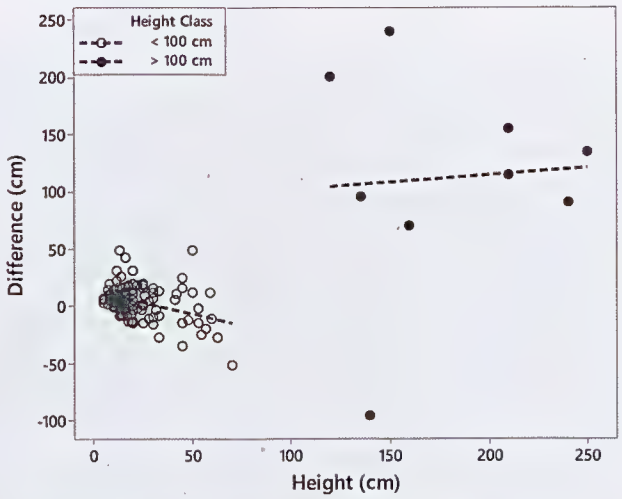

FIG. 2 — Difference in *Eucalyptus coccifera* height between 2006 and 2016 for paired trees related to height in 2006 (total = 111, < 100 cm = 102, > 100 cm = 9), showing lines of best fit.

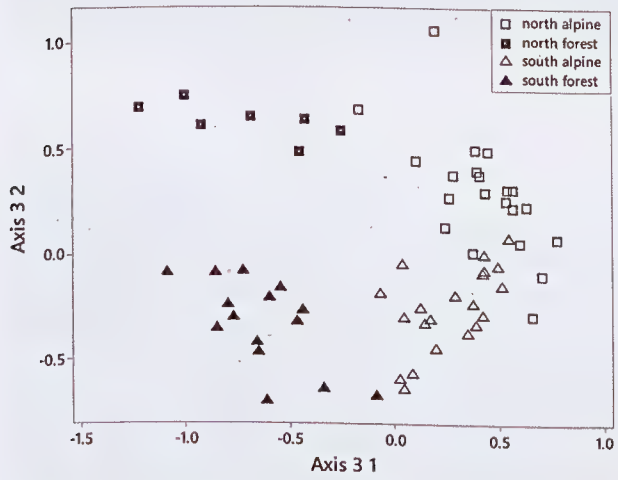

FIG. 3 — Difference in floristic composition between north- and south-facing slopes. "Alpine" describes the vegetation characteristics of the upper quadrats while "forest" describes the lower quadrats. Axis 3 1 is related to "alpineness", with higher values suggesting a floristic composition more affiliated with the alpine vegetation of the upper quadrats, while a lower value suggests closer affiliation with the forest vegetation of the lower quadrats. Axis 3 2 is related to aspect, with higher values suggesting an affiliation with the vegetation of the north-facing slopes, and lower values the south-facing slopes.

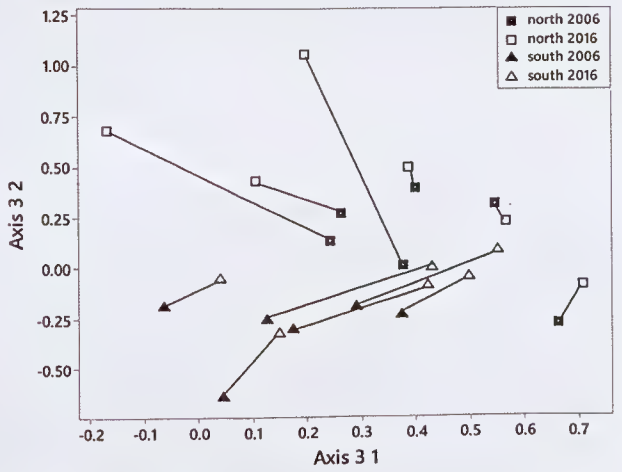

FIG. 4 — Direction of change for floristic composition for quadrats on north- and south-facing slopes between 2006 and 2016. Axis 3 1 is related to "alpineness", with higher values suggesting a floristic composition more affiliated with the alpine vegetation of the upper quadrats, and a lower value suggesting closer affiliation with the forest vegetation of the lower quadrats. Axis 3 2 is related to aspect, with higher values suggesting an affiliation with the vegetation of the north-facing slopes, and lower values the south-facing slopes.

Individual *E. coccifera* plants were perceptible at higher altitudes on the north-facing slope in 2015 than in 1953 (pl. 3). On the south-facing slope more individuals were perceptible in 2015 than in 1953 in some *E. coccifera* clusters (pl. 2). However, none of the individual *E. coccifera* above the 1953 treeline had exceeded 3 m in height by 2016.

Eucalyptus coccifera density decreased in the alpine quadrat furthest from the boundary (1) and in the quadrat second from the boundary (4), but increased in other quadrats (table 1). The median height of *E. coccifera* increased by 70%, from 20 cm in 2006 to 34 cm in 2016. *E. coccifera* heights in the quadrat closest to the boundary (5) were greater than those further away for 2006 (n = 384, H = 26.8, df = 4, $p < 0.001$) and 2016 (n = 584, H = 126.8, df = 4, $p < 0.001$). In both 2006 and 2016 the median height was greater on the south-facing slope (n = 26, median = 50 cm) than on the north-facing slope (n = 584, median = 33 cm). The number of *E. coccifera* increased for all height classes (table 2).

For all paired *E. coccifera*, those with 2006 heights greater than 100 cm showed the greatest increase in height, with a median difference of 115 cm, while those in the less than 50 cm and 50–100 cm height classes increased by a median of 5.5 cm and decreased by 13 cm respectively (n = 111, H = 18.68, df = 2, $p < 0.001$). Paired *E. coccifera* with a height greater than 100 cm in 2006 had no tendency in height difference between 2006 and 2016 with height (r^2 = 0.4, df = 8, p = 0.864), whereas the shorter individuals in 2006 had a negative relationship (r^2 = 12.8, df = 101, $p < 0.001$), with 58.8% of *E. coccifera* in this height class increasing in height, and 41.2% decreasing in height (fig. 2).

Aspect had a significant effect on growth for all paired *E. coccifera* , with those on the north-facing slope increasing in height by a median of 4 cm, compared to the median increase of 14.5 cm on the south-facing slope (n = 111, H = 4.95, df = 1, p = 0.026). However, this difference was strongly influenced by several tall (> 100 cm) individuals on the south-facing slope. When considering only those trees less than 100 cm, aspect had no significant effect on *E. coccifera* growth (n = 111, H = 0.09, df = 1, p = 0.758).

There was no relationship between the change in floristic composition over time, represented by the "date" axis, with change in *E. coccifera* height (R^2 = 1.2, df = 1, p = 0.732) or density (R^2 = 0.1, df = 1, p = 0.926). The degree of floristic "alpineness" above the treeline (quadrats 1 to 5) differed from quadrats below the treeline (quadrats 6 +) (R^2 = 85.1, df = 9, $p < 0.001$). Aspect also had an influence on vegetation, with the north- and south-facing slopes displaying different assemblages of taxa (R^2 = 44.58, df = 1, $p < 0.001$, fig. 3). Ten species changed in cover between 2006 and 2016, with the strongest increasers being the alpine-dominant shrub, *Orites acicularis*, and *E. coccifera*, and the strongest decreasers being grass and herb species (table 3).

Floristic composition changed more on the north-facing slope than the south-facing slope (fig. 4). On the south-facing slope the quadrats became more alpine, while the quadrats on the north-facing slope largely became less alpine (fig. 4).

The repeat photographs show increases in alpine shrubs, particularly *O. acicularis*, and an increase in *E. coccifera* abundance near the treeline. *Eucalyptus coccifera* below the treeline increased both in height and density (pl. 3).

DISCUSSION

The climatic treeline at the study site on Mount Rufus, identified from aerial photographs and ground truthing, is approximately 1220 m on the north-facing slope, and 1210 m on the south-facing slope. Aspect-related differences in levels of insolation (Kirkpatrick & Nunez 1980) make summer temperatures higher on north-facing slopes.

The increase in *E. coccifera* height and density between 2006 and 2016 was consistent with the increase in number of individuals of *E. coccifera* above the treeline evident between the 1953 and 2015 photographs, suggesting that a slow invasion has been taking place over the past 62 years, or that the 1965 fire created conditions suited to establishment of seedlings, although Green (2009) found

TABLE 1 — Average density of *Eucalyptus coccifera* for each quadrat above the treeline between the years 2006 and 2016.

Quadrat	Density 2006 (trees/ha)	Density 2016 (trees/ha)	Difference (trees/ha)	Percentage change
1	433.3	400.0	–33.3	–7.7
2	283.3	466.7	183.3	64.7
3	800.0	800.0	0.0	0.0
4	1683.3	1066.7	–616.7	–36.6
5	3200.0	7000.0	3800.0	118.8

TABLE 2 — Change in number of *Eucalyptus coccifera* measured for each height class in 2006 and 2016.

Height class	Number 2006	Number 2016	Difference	Percentage change
0–50 cm	350	435	85	24.3
50–100 cm	22	122	100	454.5
>100 cm	12	27	15	125
Total	384	584	200	52.1

PLATE 3 — Photographs showing vegetation change between 2006 (left) and 2016 (right): from top, photopoint T3 0 (Transect 3 0 m) South, T3 50 South, T6 0 East, T6 50 East.

TABLE 3 — Mean percentage cover of taxa that experienced a significant change between 2006 and 2016 in the twelve repeat quadrats.

Taxon	Percentage Cover 2006	Percentage Cover 2016	Percentage Change	*p*
Coprosma nitida (sh)	0.29	0.13	–55.17	<0.05
Eucalyptus coccifera (tr)	1.54	4.58	197.40	<0.05
Gonocarpus montanus (h)	0.33	0.08	–75.76	<0.01
Oreobolus acutifolius (se)	2.04	4.29	110.29	<0.05
Oreobolus pumilio (se)	0.37	0.04	–89.19	<0.05
Orites acicularis (sh)	2.75	7.92	188.00	<0.01
Ozothamnus rodwayi (sh)	11.54	3.46	–70.02	<0.01
Poa spp. (grass)	9.42	1.21	–87.15	<0.01
Richea sprengelioides (sh)	5.33	1.17	–78.05	<0.01
Senecio leptocarpus (h)	0.79	0.08	–89.87	<0.01

h = herb, se = sedge, sh = shrub, tr = tree.
p = probability from paired t-test.

no effect of fire on the establishment of eucalypts above the Snowy Mountains alpine treeline. Even though no change in climate has been observed at Lake St Clair in the past 25 years, there are no direct climatic data from Mount Rufus, leaving open the possibility of variable climatic change over the altitudinal gradient.

One possible explanation for the increase in tree height and density could be an increase in days of snow cover in the winter months. Snow cover protects underlying vegetation from freezing winter temperatures and abrasive winds (McVean 1958). Grose (1960) found that *E. delegatensis* RT Baker seedlings whose crowns protruded from the snow were susceptible to death, as they were exposed to the harsh freeze/thaw conditions at the surface of the snow, the "kill zone". Those seedlings that were small enough to be buried entirely below the snow were insulated from the harsher conditions at the surface of the snow. The different height changes for each height class observed at the study site are consistent with this observation. An increase in depth and/or duration of snow at the study site could assist in protecting small *E. coccifera* seedlings in the colder months. The past three decades have seen a small increase in the number of days that experience snow at Mount Rufus (Kirkpatrick pers. comm. 2016), which is likely to have been associated with greater snow depths and duration of snow lie on the ground, although these more important predictors of tree survival have not been measured. The effect of this snow cover protection would be most pronounced on the north-facing slope, where the greatest amount of snow accumulates in a snow patch (pl. 4), which is the same area in which the greatest increase in *E. coccifera* height and density were observed.

Our data suggest that, once trees exceeded 100 cm height they were able to overcome obstacles to growth. The negative relationship between growth and 2006 size evident for trees below 100 cm in height in 2006 could possibly indicate that some cycle of regeneration is taking place, with trees below a certain height threshold dying back then resprouting from lignotubers. Once these survivors have reached 100 cm, the putative freeze/thaw that kills off the medium-sized *E. coccifera* is absent, and they continue to grow. The high number of large, gnarled lignotubers supporting small *E. coccifera* observed at the site support this hypothesis, as the age of the lignotuber is clearly much greater than that of the regrowth it supports.

The differences in vegetation composition change between the north- and south-facing slopes may relate to the greater dryness and instability on the steep, well-insolated north-facing slope, where snow accumulates to greater depth in winter than on the gentler south-facing slope. *E. coccifera* is better suited to well-drained rather than waterlogged conditions (Gilfedder 1988, Kirkpatrick & Gibson 1998). Although there was a greater increase in tree density on the north-facing slope, in most quadrats the increase was not sufficient to influence vegetation composition as shown by the lack of relationship between the variables related to *E. coccifera* and those related to species composition.

On the southern slope, the increase in "alpine" vegetation may be related to succession processes, with vegetation still recovering from fire. These succession processes may be more pronounced on the south-facing aspect than the north due to the less regular disturbance compared to that experienced by the north. The obligate seed regenerator, *Orites acicularis* (R.Br.) Roem. & Schult., has greater cover on unburned sites than in burned sites elsewhere in Tasmania (Kirkpatrick *et al.* 2010). It appears to be slowly recovering since the area was last burnt in 1965 at the same rate as observed on Mt Wellington (Kirkpatrick *et al.* 2002b). Conversely, the decreasers at Mt Rufus have all been found in higher numbers in burned than unburned sites in alpine Tasmania (Kirkpatrick *et al.* 2010).

In terms of future vegetation composition, the impacts of climate change are relevant, as lightning fire has become more frequent in western Tasmania (Marsden-Smedley 2009). If fires were to become more frequent at Mt Rufus, major vegetation change could be anticipated.

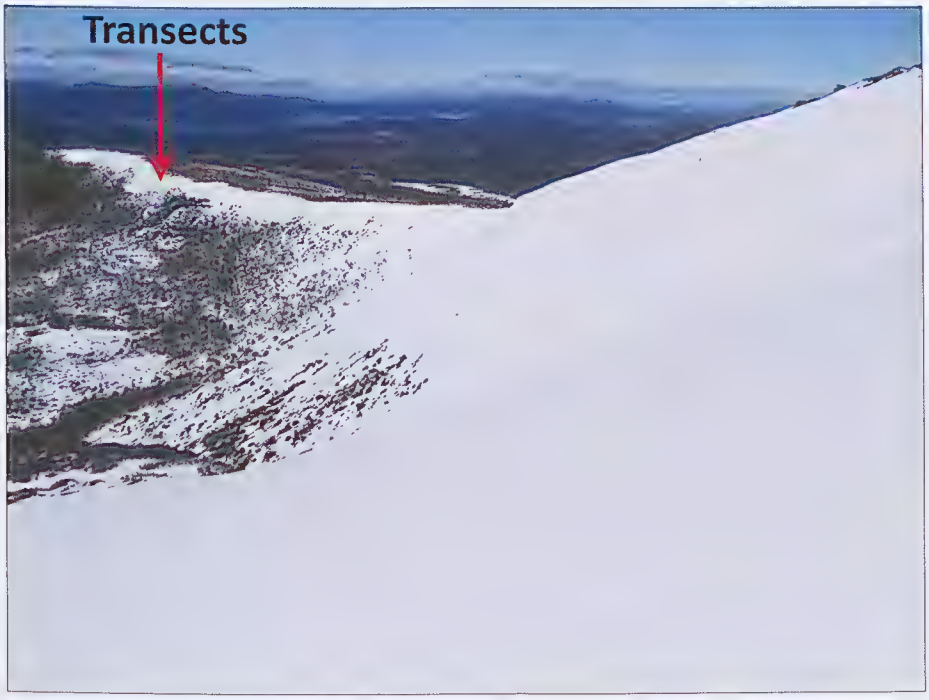

PLATE 4 — Snow accumulation on the eastern and northern slopes of Mt Rufus, Tasmania, looking east towards the transect locations. Photograph taken 1 September 2015 (Source: B. Annandale).

The lack of advance of the *E. coccifera* treeline in the past 10 years, or during the past six decades, is consistent with the persistence of abrupt treelines noted globally, even where climate has changed, by Harsch *et al.* (2009). This phenomenon has also been observed by Green (2009) in the Snowy Mountains. However, tree height and density has increased in the past 10 years, although this has not yet brought about a shift in treeline location, as all trees remain less than 3 m in height.

It is difficult to determine whether the increase in height and density is a result of climatic change or a symptom of recovery from the 1965 fire. Floristic composition has changed differently depending on aspect, with the vegetation situated on the south-facing slope becoming more dominated by alpine shrubs, and that on the north-facing slope becoming more closely similar to the vegetation below the treeline. As individuals of *E. coccifera* increase in height they may transgress the 3 m barrier, shifting the treeline.

We therefore conclude that there have been changes in the vegetation above the treeline, including some thickening and height growth of *E. coccifera* in its shrub stage, that there is no strong evidence for climate change, and that the hypothesis that forest species gained more dominance above the treeline is incorrect for south-facing slopes, but correct for north-facing slopes.

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REFERENCES

Bridle, K.L., Kirkpatrick, J.B., Cullen, P. & Shepherd, R.R. 2001: Recovery in alpine heath and grassland following burning and grazing, eastern Central Plateau, Tasmania. *Arctic, Antarctic and Alpine Research* **33**: 348–356.

Camac, J.S., Williams, R.J., Wahren, C.H., Jarrad, F., Hoffmann, A.A. & Vesk, P.A. 2015: Modeling rates of life form cover change in burned and unburned alpine heathland subject to experimental warming. *Oecologia* **178**: 615–628.

Colhoun, E.A., Hannan, D. & Kiernan, K. 1996: Late Wisconsin glaciation of Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* **130**: 33–45.

Costin, A.B., Gray, M., Totterdell, C.J. & Wimbush, D.J. 1979: *Kosciusko Alpine Flora*, CSIRO/ Collins, Sydney: 408 pp.

Gibson, N. & Kirkpatrick, J.B. 1992: Dynamics of a Tasmanian cushion heath community. *Journal of Vegetation Science* **3**: 647–654.

Gilfedder, L. 1988: Factors influencing the maintenance of an inverted *Eucalyptus coccifera* tree-line on the Mt Wellington Plateau, Tasmania. *Australian Journal of Ecology* **13**: 495–503.

Green, K. 2009: Causes of stability in the alpine treeline in the Snowy Mountains of Australia – a natural experiment. *Australian Journal of Botany* **57**: 171–179.

Green, K. & Pickering, C.M. 2009: The decline of snowpatches in the Snowy Mountains of Australia: importance of climate warming, variable snow and wind, *Arctic, Antarctic, and Alpine Research* **41**: 212–218.

Green, K. & Stein, J.A. 2015: Modeling the thermal zones and biodiversity on the high mountains of Meganesia: the importance of local differences. *Arctic, Antarctic, and Alpine Research* **47**: 671–680.

Greenwood, S. & Jump, A.S. 2014: Consequences of treeline shifts for the diversity and function of high altitude ecosystems, *Arctic, Antarctic, and Alpine Research* **46**: 829–840.

Grose, R.J. 1960: The silviculture of *Eucalyptus delegatensis* R.T. Baker. Unpublished PhD thesis, University of Melbourne, Melbourne.

Hagedorn, F., Shiyatov, S.G., Mazepa, V.S., Devi, N.M., Grigor'ev, A.A., Bartysh, A.A., Fomin, V.V., Kapralov, D. S., Terent'ev, M., Bugman, H. & Rigling, A. 2014: Treeline advances along the Urals mountain range—driven by improved winter conditions? *Global Change Biology* **20**: 3530–3543.

Harsch, M.A, Hulme, P.E, McGlone, M.S. & Duncan, R.P. 2009: Are treelines advancing? A global meta-analysis of treeline response to climate warming. *Ecology Letters* **12**: 1040–1049.

Kirkpatrick, J.B. 1982: Phytogeographical analysis of Tasmanian alpine floras. *Journal of Biogeography* **9**: 255–271.

Kirkpatrick, J.B. 1983: Treeless plant communities of the Tasmanian high country. *Proceedings of the Ecological Society of Australia* **12**: 61–77.

Kirkpatrick, J.B. & Balmer, J. 1991: The vegetation and flora of the Cradle Mountain-Pencil Pine area, Tasmania. *In* Smith, S.J. (ed.): Aspects of Tasmanian botany. Royal Society of Tasmania, Hobart: 119–148.

Kirkpatrick, J.B. & Bridle, K.L. 2013: Natural and cultural histories of fire differ between Tasmanian and mainland Australian alpine vegetation, *Australian Journal of Botany* **61**: 465–474.

Kirkpatrick, J.B. & Bridle, K.L. 2016: Grazing and the absence of fire promote the dominance of an unpalatable shrub in a patch mosaic cyclic successional system. *Australian Journal of Botany* **64**: 45–50.

Kirkpatrick, J.B., Bridle, K.L. & Dickinson, K.J.M. 2010: Decades-scale vegetation change in burned and unburned alpine coniferous heath. *Australian Journal of Botany* **58**: 453–462.

Kirkpatrick, J.B., Bridle, K. & Lynch, A.J.J. 2002a: Changes in vegetation and landforms at Hill One, Tasmania. *Australian Journal of Botany* **50**: 753–759.

Kirkpatrick, J.B., Bridle, K.L. & Wild, A.S. 2002b: Succession after fire in alpine vegetation on Mount Wellington, Tasmania. *Australian Journal of Botany* **50**: 145–154.

Kirkpatrick, J.B. & Dickinson, K.J.M. 1984: The impact of fire on Tasmanian alpine vegetation and soils. *Australian Journal of Botany* **32**: 613–629.

Kirkpatrick, J.B. & Gibson, N. 1998: Responses to waterlogging and frost related to the topographic sequences of eucalypt species at three sites in central Tasmania, *Papers and Proceedings of the Royal Society of Tasmania* **132**: 31–34.

Kirkpatrick, J.B. and Nunez, M. 1980: Vegetation-radiation relationships in mountainous terrain: eucalypt-dominated vegetation in the Risdon Hills, Tasmania. *Journal of Biogeography* **7**: 197–208.

Marsden-Smedley, J.B. 2009: Planned burning in Tasmania: operational guidelines and review of current knowledge. Fire Management Section, Parks and Wildlife Service, Department of Primary Industries, Parks, Water and the Environment, Hobart, Tasmania: 100 pp.

McVean, D.N. 1958: Snow cover and vegetation in the Scottish Highlands, *Weather* **13**: 197–200.

Minchin, P. 1990: *DECODA – Database for ecological community data, version 2.02.* Research School of Pacific Studies, Australian National University, Canberra.

Minitab Inc. 2010: *Minitab Users Guide Release 16.* Minitab Inc., USA.

Nunez, N. & Colhoun, E.A. 1986: A note on air temperature lapse rates on Mount Wellington, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* **120**: 11–15.

Parry, J., Kirkpatrick, J.B. & Marsden-Smedley, J. 2016: Explaining the distribution, structure and species composition of snow patch vegetation in Tasmania, Australia. *Australian Journal of Botany* **64**: 484–491.

Paulsen, J. & Körner, C. 2014: A climate-based model to predict potential treeline position around the globe. *Alpine Botany* **124**: 1–12.

Pickering, C., Hill, W. & Green, K. 2008: Vascular plant diversity and climate change in the alpine zone of the Snowy Mountains, Australia. *Biodiversity Conservation* **17**: 1627–1644.

Pyrke, A.F. & Kirkpatrick, J.B. 1994: Growth rate and basal area response curves of four *Eucalyptus* species on Mt. Wellington, Tasmania. *Journal of Vegetation Science* **5**: 13–24.

Settele, J., Scholes, R., Betts, R., Bunn, S., Leadley, P., Nepstad, D., Overpeck, J.T. & Taboada, M.A. 2014: Terrestrial and inland water systems. *In* Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, K.L., Ebi, Y.O. Estrada, R.C., Genova, B., Girma, E.S., Kissel, A.N., Levy, S., MacCracken, P.R., Mastrandrea, M.D. & White, L.L. (eds): Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge: 271–359.

Shaw, M.J., Potts, B.M., & Reid, J.B. 1984. Variation within and between *Eucalyptus nitida* Hook. F. and *E. coccifera* Hook. F. *Australian Journal of Botany* **32**: 641–654.

Styger, J. & Balmer, J. 2009: Alpine treeline ecotone monitoring program within the Tasmanian Wilderness World Heritage Area. Nature Conservation Report 2009/4, Department of Primary Industries, Parks, Water and Environment, Hobart.

UNESCO 2008. Operation guidelines for the implementation of the World Heritage Convention. World Heritage Centre. <http://whc.unesco.org/archive/opguide08-en.pdf> (accessed 20 February 2016).

Venn, S.E., Green, K., Pickering, C.M. & Morgan J.W. 2011: Using plant functional traits to explain community composition across a strong environmental filter in Australian alpine snowpatches. *Plant Ecology* **212**: 1491–9.

Venn, S.E., Pickering, C.M. & Green, K. 2012: Short-term variation in species richness across an altitudinal gradient of alpine summits. *Biodiversity and Conservation* **21**: 3157–3186.

Venn, S., Pickering, C. & Green, K. 2014: Spatial and temporal functional changes in alpine summit vegetation are driven by increases in shrubs and graminoids, *Annals of Botany Plants* **6** (plu008): 1–15. <http://aobpla.oxfordjournals.org/content/6/plu008.full.pdf+html> (accessed 6 March 2016).

Williams, K.J., & Potts, B.M. 1996 The natural distribution of *Eucalyptus* species in Tasmania. *TASFORESTS* **8**: 39–165.

Williams, R.J., Wahren, C.-H., Stott, K.A.J., Camac, J.S., White, M., Burns, E., Harris, S., Nash, M., Morgan, J.W., Venn, S., Papst, W.A. & Hoffmann, A.A. 2015: An International Union for the Conservation of Nature Red List ecosystems risk assessment for alpine snow patch herbfields, South-Eastern Australia. *Austral Ecology* **40**: 433–443.

Williams, R.J., Wahren, C.-H., Tolsma, A.D., Sanecki, G.M., Papst, W.A., Myers, B.A., McDougall, K.L., Heinze, D.A. & Green, K. 2008: Large fires in Australian alpine landscapes: their part in the historical fire regime and their impacts on alpine biodiversity. *International Journal of Wildland Fire* **17**: 793–808.

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CONTRIBUTIONS TO A CATALOGUE OF ALIEN PLANTS IN TASMANIA IV

by Matthew L. Baker

(with three text-figures and four plates)

Baker, M. L. 2016(15:xii): Contributions to a catalogue of alien plants in Tasmania IV. *Papers and Proceedings of the Royal Society of Tasmania* 150(2): 19–26. ISSN 0080-4703. Tasmanian Herbarium, Tasmanian Museum and Art Gallery, PO Box 5058, UTAS LPO, Sandy Bay, Tasmania 7005, Australia. Email: Matthew.Baker@tmag.tas.gov.au

The status of four alien plant taxa in Tasmania is discussed. *Mirabilis jalapa* L., *Phytolacca octandra* L., *Coleonema pulchellum* I.Williams and *Gomphocarpus fruticosus* (L.) W.T.Aiton are ornamentals that are now recognised as naturalised in Tasmania. A description for each taxon is provided and distribution and habitat details are discussed. The status of two species that are recorded as naturalised in Tasmania but are not represented in the Tasmanian Herbarium collection was also investigated. *Veronica peregrina* L. is known from two collections from Tasmania whilst the name *Silene longicaulis* Pourr. ex. Lag. was found to be misapplied to Tasmanian specimens of *Silene colorata* Poir.
Key Words: naturalised, exotic, weeds, introduced, flora, *Mirabilis, Phytolacca, Coleonema, Gomphocarpus, Veronica, Silene.*

INTRODUCTION

Management of Tasmania's alien flora requires an accurate and up-to-date account of the taxa present. This paper is the fourth of a series (Baker 2005, 2007, 2011) which aims to ensure that taxa that become naturalised in Tasmania are formally recorded; that taxa that are present in Tasmania, but have not become fully naturalised ("sparingly naturalised" in the sense of Buchanan (2005) and Baker (2005)) are likewise recorded; that new incursions of alien taxa are recorded; and to maintain up-to-date names for taxa that have been affected by nomenclatural change. In this paper, four species that were introduced as garden ornamentals (*Mirabilis jalapa* L., *Phytolacca octandra* L., *Coleonema pulchellum* I.Williams and *Gomphocarpus fruticosus* (L.) W.T.Aiton) are treated, giving diagnostic descriptions and notes on their distribution. The status of two ruderal herbs that are recorded as naturalised in Tasmania but are not represented in the Tasmanian Herbarium collection (*Veronica peregrina* L. and *Silene longicaulis* Pourr. ex. Lag.) was also investigated. It is hoped that this information will increase general knowledge of distribution of naturalised alien taxa in Tasmania and raise community awareness of plants that have the potential to become naturalised.

Reports of new incursions, naturalised and sparingly naturalised species are welcomed by the author. Specimens and relevant collection information can be forwarded to the Tasmanian Herbarium.

MATERIALS AND METHODS

Primary sources used for this study are specimens held in the Tasmanian Herbarium (HO). Herbarium abbreviations follow Holmgren *et al.* (1990). Identifications by the author and others were checked against literature and, where available, reliably identified voucher specimens.

Voucher specimens for all species treated have been lodged in the Tasmanian Herbarium. The naturalised status of treated species is based upon field observations made by the author and others and, when available, from notes accompanying specimens.

The placement of genera in families follows the *Flora of Tasmania Online* (Duretto 2009).

Citations of synonyms are limited to names used in Tasmanian literature. Tasmanian distributions follow regions proposed by the Interim Biogeographic Regionalisation for Australia (IBRA). Geographical origins of plants treated have been determined from various published sources. Definitions of "alien" and "naturalised" and "sparingly naturalised" are in accordance with Baker (2005).

The naturalised species treated in this paper were chosen because they have not been discussed in Tasmanian botanical literature. They are species that have been recently collected and observed in naturalised populations by the author.

NATURALISED TAXA IN TASMANIA

1. *Mirabilis jalapa* L., *Sp. Pl. 1*: 177 (1753) var. ***jalapa*** (Nyctaginaceae)

Common name: Four O'clock Plant, Marvel-of-Peru

Illustrations: Richardson *et al.* (2006: 317); Richardson *et al.* (2011: 384); Jacobs & Harden (1990: 187); Jessop (1986a: fig. 104c); Phillips & Rix (2002: 82); Spencer (1997: 184); (pl. 1).

Description: Erect, bushy perennial herbs with thick tuberous rootstocks. Plants to 1.5 m tall; nodes swollen. Leaves opposite; petiole to 25 mm long; lamina ovate to broad-lanceolate, up to 120 mm long, 20–50 mm wide; base cuneate to obtuse; margin minutely undulate with sparse multicellular hairs; apex acute. Inflorescences compact, axillary and terminal cymes. Bracts five, connate, calyx-like. Perianth 5-lobed, 2–3 cm long, white, yellow or magenta or a variegated mixture of these colours; stamens 5–6. Fruit a subglobose achene, with base prominently constricted, *c.* 7 mm long, 5 mm diam., dark brown to black, smooth or faintly rugose, glabrous.

A comprehensive description can be found in Le Duc (1995).

Mirabilis jalapa flowers mainly from January to May and fruits from April to July. The species can be recognised by its funnel-shaped, brightly and usually multi-coloured flowers that open in the afternoon.

Discussion: *Mirabilis* L. is a genus of about 60 species that are native to North and South America with one

PLATE 1 — *Mirabilis jalapa*: (A) flowering branch; (B) developing flowers; (C) dissected flower; (D) ripe seed.

species in the Himalayas (Le Duc 1995). Several species are cultivated throughout the world, especially in frost-free regions, the most commonly cultivated species being *M. jalapa*.

Mirabilis jalapa is thought to be native to Mexico where it has had a long history of cultivation for its medicinal properties and showy flowers (Le Duc 1995). It is widely cultivated and naturalised throughout the world, especially in tropical and subtropical areas (Le Duc 1995). In Australia, it is naturalised in Western Australia, South Australia, Queensland, New South Wales and Tasmania. It is considered to be sparingly naturalised in Victoria where it is known only from two locations. In Tasmania, it has been recorded in naturalised populations at waste disposal sites near Scottsdale and St Helens. It has also been recorded as persisting in a long abandoned garden on Deal Island (fig. 1). The earliest Tasmanian collection, made in 1961, states that it was collected from the "North West" but no further information regarding its status is noted. It is cultivated in gardens throughout Tasmania.

First record: 1961, J. Somerville.

Specimens examined: **TASMANIA**: *Flinders* (FLI): Garden Cove, Deal Island, 1 May 2010, *P.A.Tyson 988* (HO); Stieglitz Tip (disused), St Helens, 13 Feb. 2009, *M.L.Baker 1980, 1981 & G.S. Stewart* (HO); *Tasmanian Northern Slopes* (TNS): North West, 1961, *J.Somerville s.n.* (HO); *Ben Lomond* (BEL): Scottsdale tip off Bridport Road, 200 m N of Jetsons Road junction, 11 Jan. 2005, *M.L.Baker 1403 & A.M.Gray* (HO).

2. *Phytolacca octandra* L., *Sp. Pl.*, ed 2: 631 (1762). (Phytolaccaceae)

Common name: Inkweed, Red Ink Plant, Dyeberry, Poke Weed

Illustrations: Richardson *et al.* (2006: 334); Richardson *et al.* (2011: 410); Jessop (1986b: fig. 100); Harden (1990: 176); Walsh (1996: fig. 21a-c); Hewson (1984: fig. 1a); (pl. 2).

PLATE 2 — *Phytolacca octandra*: (A) flowering and fruiting branch; (B) maturing raceme with ripe and developing fruit; (C) individual flower; (D) developing fruit; (E) ripe fruit; (F) calyx after fruit has dehisced; (G) seed.

Description: Shrub-like perennial herb to 2 m tall. Stems glabrous, woody at base, more or less succulent above, green to reddish. Leaves alternate, elliptic to lanceolate, 40–120(–250) mm long, 10–40(–130) mm wide; petiole almost sessile to 25(–50) mm long; adaxial surface glabrous, glossy, green; abaxial surface less glossy; base attenuate; margin slightly recurved, minutely and irregularly undulate; apex acute. Inflorescence a many-flowered, leaf-opposed raceme up to 16 cm long. Flowers on pedicels up to 2 mm long, subtended by a single lanceolate bract and a pair of smaller bracteoles. Perianth in one whorl of 5 petaloid tepals; tepals ovate, *c.* 3 mm long, white, green or reddish-purple; stamens usually 8. Fruit a berry, depressed-globular, 5–10 mm diam., with up to eight single-seeded lobes, green at first, ripening to purplish-black. Seed lenticular, *c.* 3 mm diam, shiny, black.

A comprehensive description can be found in Nowicke (1968).

Phytolacca octandra flowers and fruits throughout the year. Leaves of up to 25 cm long and 13 cm wide have been reported in Australian literature (Walsh 1996). Leaves *c.* 20 cm long have been observed on shaded plants at King Island whilst those of plants in non-shady habitats are much reduced in size (M. Wapstra pers. comm). *Phytolacca octandra* can be readily distinguished from other Tasmanian plants by the presence of purplish-black berries in spike-like infructescences.

Discussion: *Phytolacca* L. is a genus of about 20–25 species (Nowicke 1968, Mabberley 2008). It is cosmopolitan in its distribution although it is mostly associated with the warmer regions of the Americas (Nowicke 1968, Hewson 1984). The genus is naturalised in Australia and is represented by four species (*P. americana* L., *P. dioica* L., *P. octandra* L. and *P. rivinoides* Kunth & C.D.Bouche). In Tasmania, only *P. octandra* is naturalised.

Phytolacca octandra is a more or less cosmopolitan species (Nowicke 1968). Introduced to Australia as a

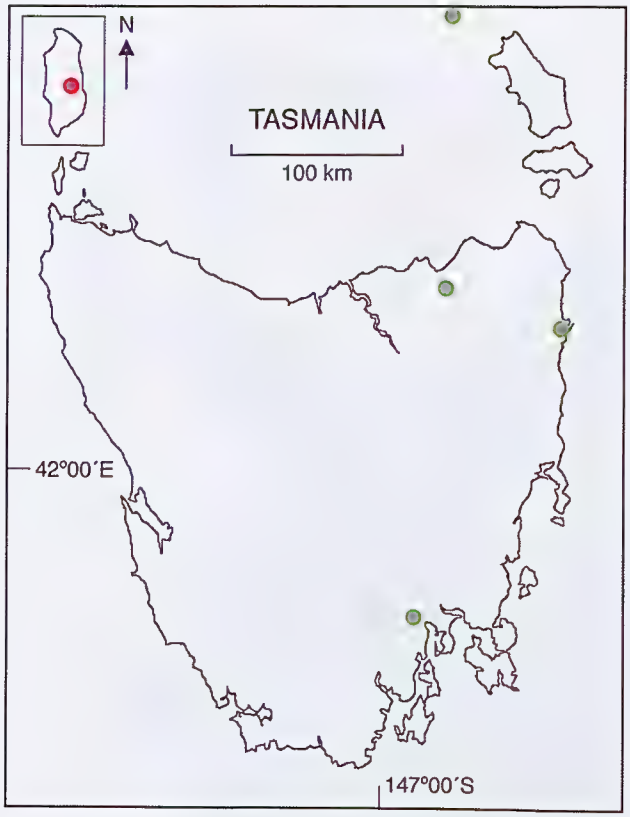

FIG. 1 — Geographical distribution of *Mirabilis jalapa* (green) and *Phytolacca octandra* (red) as known from herbarium specimens.

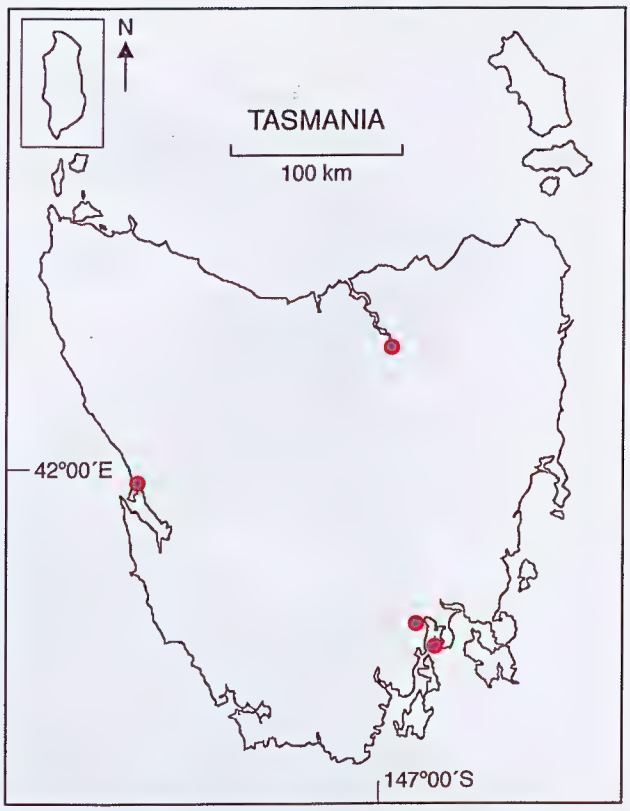

FIG. 2 — Geographical distribution of *Coleonema pulchellum* as known from herbarium specimens.

garden plant, it is now naturalised in Western Australia, South Australia, Queensland, New South Wales, Norfolk Island, Australian Capital Territory, Victoria and Tasmania (CHAH–APC 2016, The Government of South Australia 2016) and is widespread in coastal and inland regions. In South Australia, it is known from only two specimens (CHAH–AVH 2016). In Tasmania, it is naturalised only on King Island (fig. 1) where it was known in the 1980s from a single plant. It has increased its range and is now a common component of about 1.5 km of roadside verge, growing along both sides of the road and in adjacent paddocks. It has also formed dense thickets within nearby *Melaleuca ericifolia* Sm.-*Acacia melanoxylon* R.Br. swamp. The naturalised population is thought to have spread from cultivated plants.

First record: 2009, M. Wapstra.

Specimens examined: **TASMANIA**: *King* (KIN): Fraser River, King Island, 25 Mar. 2009, *M.Wapstra 697, R.B.Schahinger & M.Larcombe* (HO); Fraser River area, King Island, 25 Mar. 2009, *M.Wapstra 698, M.Larcombe & R.B.Schahinger* (HO); Fraser Road, McSweyn block. King Island, 5 Apr. 2009, *M.Batey, 7* (HO). **WESTERN AUSTRALIA**: 3 km SW of Albany Highway on Mt Barker Hill Road, 3 km SW of Mt Barker, 1 May 1996, *B.J.Lepschi 2572 & T.R.Lally* (HO). **NEW SOUTH WALES**: Lake Bathurst, W shore. Abandoned boating shed, 2.5 km NE of Tarago, 28 Dec. 1992, *B.J.Lepschi 911* (HO). **QUEENSLAND**: Statue Bay, Yeppoon, 30 May 1985, *A.M.Buchanan 6856* (HO). **VICTORIA**: The You Yangs, N end of range, 23 May 1988, *A.M.Buchanan 11017* (HO). **NEW ZEALAND**: Warawara Forest; 1km NE of Mitimiti on banks of Taikarawa Stream, 26 Apr. 1990, *J.M.Fox 55 & P.J.Brownsey* (HO).

3. *Coleonema pulchellum* I.Williams, *J. S. African Bot.* 47(1): 89 (1981). (Rutaceae)

Common name: Diosma

Illustrations: Richardson *et al.* (2006: 371); Richardson *et al.* (2011: 470); Spencer (2002: 15); (pl. 3).

Description: Rounded shrub to 1(–2) m tall. Stems finely pubescent, becoming glabrous with age. Leaves aromatic, alternate, linear-lanceolate, up to 10 mm long, up to 1 mm wide; petiole up to 1 mm long; adaxial surface ± flat, without glands; abaxial surface convex, with two rows of sunken glands; margin with a single row of antrorse hairs; apex drawn out to a very fine point. Inflorescence of solitary flowers in axils towards the ends of branches. Flowers 5-merous, subtended by a pair of leaf-like bracts and several smaller bracteoles. Sepals *c.* 2.5 mm long, *c.* 1.5 mm wide, with translucent and ciliate margins. Petals up to 5.5 mm long, pink at first, fading to almost white, narrowing at about the midpoint to a distinct claw; claw *c.* 2.5 mm long, ± erect; limb *c.* 3 mm long, obovate to broad-orbicular, spreading at *c.* 90° to the claw. Stamens about as long as claw. Staminodes joined to the petal claws for most of their length. Ovary 5-carpellate, within a cup-like disc. Fruit dehiscent, with horned mericarps, up to 5 mm long. Seed *c.* 3 mm long.

A comprehensive description can be found in Williams (1981).

Coleonema pulchellum flowers and fruits mainly from winter through to spring. The species can be readily distinguished from other Tasmanian plants by having aromatic leaves with two rows of glands on the abaxial surface. Shrubs reaching heights of two metres are found in the species' native range. However, in Tasmania, plants are usually less than 1 m tall.

PLATE 3 — *Coleonema pulchellum*: (A) flowering branch; (B) individual flower; (C) developing fruit; (D) mature fruit.

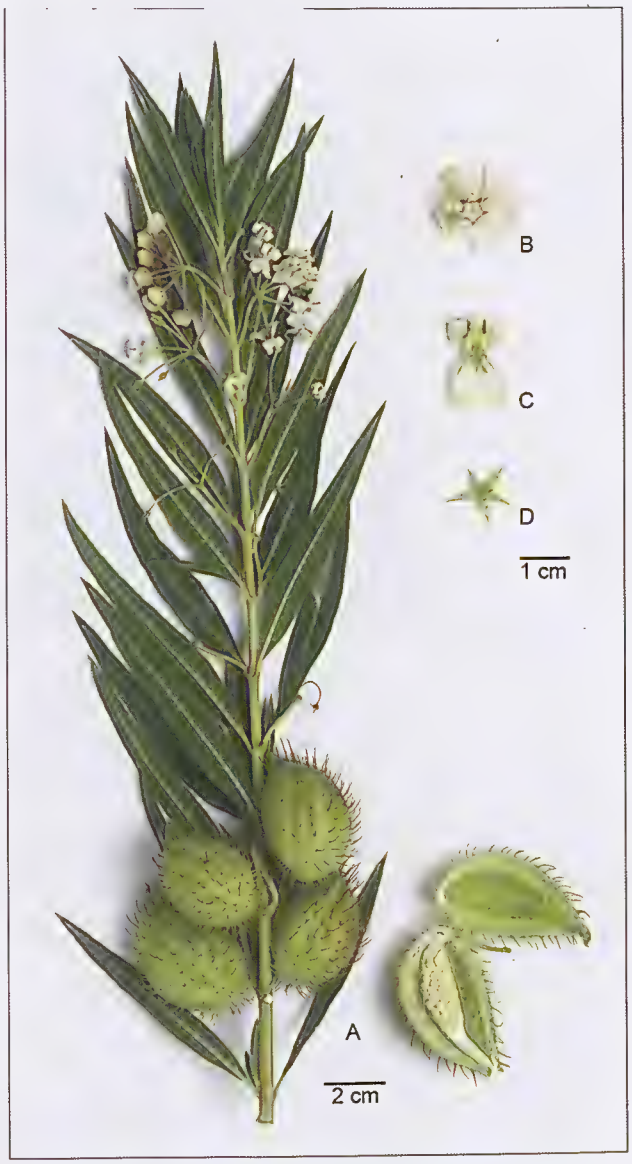

PLATE 4 — *Gomphocarpus fruticosus*: (A) flowering and fruiting branch with a dissected fruit; (B) apical view of flower; (C) dissected flower; (D) calyx.

Discussion: *Coleonema* Bartl. & H.L.Wendl. is a genus of eight species (Williams 1981) native to South Africa (Kubitzki *et al.* 2011). The genus is naturalised in Australia and is represented by two species that were introduced as garden plants: *C. album* (Thunb.) Bartl. & H.L.Wendl. (naturalised in Western Australia) and *C. pulchellum* L. However, Wilson (2013) states that the name *C. album* (Thunb.) Bartl. & H.L.Wendl. has been misapplied by various authors (e.g., Marchant *et al.* 1987; Paczkowska & Chapman 2000; Wheeler *et al.* 2002) to Western Australian material of *C. pulchellum*. This Western Australian material was not examined in this study. In Tasmania, only *C. pulchellum* is naturalised.

Coleonema pulchellum is native to coastal areas of South Africa (Williams 1981). In Australia, it is naturalised in Victoria and Tasmania. In Tasmania, it is known from several sites where it has most likely spread from cultivated plants (fig. 2). A population in excess of 50 plants was recorded along the roadside at South Arm. Numerous seedlings were also recorded growing near a mature cultivated specimen in a garden bed at Strahan and a single mature plant was recorded growing amongst native vegetation at the Trevallyn Nature Recreation Reserve. It is a very commonly cultivated plant in Tasmania and naturalised plants are expected to be more common than reported here. The name *C. pulchrum* (a shrub with longer leaves and larger flowers), has been widely misapplied to *C. pulchellum*, especially in the horticultural trade (Williams 1981, Spencer 2002).

First record: 2000, R. Glazik.

Specimens examined: **TASMANIA**: *Tasmanian SE* (TSE): Nelson Road, Hobart, 9 Feb. 1985, *A.M.Buchanan 5593* (cultivated) (HO); South Arm, 30 Sep. 2000, *R.Glazik s.n.* (HO). *Tasmanian West* (TWE): Strahan, 21 Nov. 2005, *M.Baker 1675 & A.M.Gray* (HO). *Tasmanian Northern Midlands* (TNM): Trevallyn Nature Recreation Area, 20 Sep. 2011, *R.Skabo s.n.* (HO).

4. *Gomphocarpus fruticosus* (L.) W.T.Aiton, *Hortus Kew.* (W.T.Aiton), ed. 2. 2: 80 (1811). subsp. ***fruticosus*** (Apocynaceae, Asclepiadaceae)

Synonym: Asclepias fruticosa L., *Sp. Pl.* 1: 216 (1753).

Common name: Swan Plant, Narrow-leaf Cotton-bush

Illustrations: Richardson *et al.* (2006: 109); Richardson *et al.* (2011: 133); Harden & Williams (1992: 527); Jeanes (1999: fig. 64c); Parsons and Cuthbertson (2001: 180–181); (pl. 4).

Description: Erect shrubs to 1.5 m tall. Stems finely pubescent with appressed hairs. Leaves opposite to sub-

opposite, narrowly lanceolate, 25–115 mm long, 3–12 mm wide; petiole up to 5 mm long; adaxial surface glossy, green, covered with sparsely scattered hairs; abaxial surface glabrous except for the midrib, less glossy than the adaxial surface; base cuneate; margin slightly revolute; apex acute. Inflorescences extra-axillary umbels with up to eight flowers on a peduncle up to 26 mm long. Flowers on erect pedicels up to 20 mm long, (up to 25 mm long, strongly deflexed and stouter when in fruit). Sepals five, up to 5 mm long, narrow-lanceolate to triangular, appressed hairy. Corolla lobes up to 7 mm long, united at the base, white, deflexed to spreading. Corona lobes five, attached to a staminal column. Stamens five, each with a pair of pollinia. Fruit an inflated follicle, usually one or two per inflorescence by abortion, glabrescent, covered in numerous filiform protuberances, globose, green at first, ripening to a straw colour, up to 30 mm wide and 55 mm long; apex attenuate. Seed *c.* 50 per fruit, ovoid to pyriform, concavo-convex, 4–5 mm long, 2–2.5 mm wide, rugose, brown, with a conspicuous tuft of white silky hairs.

A comprehensive description can be found in Goyder and Nicholas (2001).

Gomphocarpus fruticosus flowers from February–March and fruits from February–June. The species can be readily distinguished from other Tasmanian plants by the large inflated fruits that are covered in soft filiform protuberances.

Discussion: *Gomphocarpus* R.Br. is a genus of 20 species of mostly shrubby perennial herbs native to Africa and eastwards to the Arabian Peninsula, the Sinai Peninsula, Israel and Jordan (Goyder & Nicholas 2001). The genus is naturalised in Australia and is represented by three species (*G. cancellatus* (Burm.f.) Bruyns (South Australia and Victoria), *G. fruticosus* (all states except Northern Territory) and *G. physocarpus* E.Mey. (Western Australia, South Australia, Queensland, New South Wales and Lord Howe Island)). Hybrid swarms between *G. fruticosus* and *G. physocarpus* have been recorded in Australia (Forster 1996).

Gomphocarpus fruticosus consists of five subspecies that are native throughout southern and eastern Africa and the southern parts of the Arabian Peninsula (Saudi Arabia, Yemen and Oman) (Goyder & Nicholas 2001). It is the type subspecies (native to southern Africa as far north as southwest Angola, Botswana, Zambia and Mozambique) that is naturalised in Australia (Goyder & Nicholas 2001). In its native range, it is associated with dry sandy soils in open or disturbed places and on river banks (Goyder & Nicholas 2001). It is cultivated and widely naturalised elsewhere in warm temperate or dry subtropical areas of the world (Goyder & Nicholas 2001). The species was recorded as an alien species in Australia from as early as 1802 (for a brief account of its history in Australia see Parsons & Cuthbertson, 2001) and is now naturalised in all states and territories except for the Northern Territory (CHAH–APC 2016). In Victoria, it has been recorded as an occasional weed of disturbed sites such as roadsides, pastures and waterways (Jeanes 1999). In New South Wales, it is widespread in waste places, pastures and river banks (Harden & Williams 1992). In Tasmania, it has been recorded as a weed of roadsides, rough pastures, unkempt gardens and tip sites (fig. 3).

First record: 1928, R.M. Lester-Garland. (Photograph – Possibly cultivated)

Specimens examined: **TASMANIA**: *East Coast region* (TSE): Duke Street, Sandy Bay. Hobart, 10 May 1984, *E.Edmonds s.n.* (cultivated) (HO); Hobart, Mar. 1928, *R.M.Lester-Garland s.n.* (?Cultivated) (HO); Bellerive, grounds outside of Bellerive Cricket Oval, 5 Apr. 2007, *M.L.Baker 1792 & A.Crane* (cultivated)(HO); Seven Mile Beach Protected Area, 19 Feb. 2009, *A.Jackson s.n.* (HO); Darlington, Maria Island, 7 Mar. 2011, *M.L.Baker 2399* (HO). *Flinders region* (FLI): Prime Seal Island, 2002, *S.Harris s.n.* (HO); Summerset property, Memana, Flinders Island, 1 Feb. 1993, *R.P.Minchin s.n.* (HO); West End Road, 6 Jun. 2000, *A.M.Buchanan 15767* (HO); West End Road, Tanners Bay, Flinders Island, 3 Feb. 2012, *K.Hopkins s.n.* (HO); Cape Barren Island, Barretts Hardluck Track, 15 Sep. 2012, *P.A.Tyson 1072 & B.Tyson* (HO); Stieglitz Tip (disused), St Helens, 13 Feb. 2009, *M.L.Baker 1986 & G.S.Stewart* (HO). **NEW SOUTH WALES**: *c.* 30 km S of Singleton on Wollombi Road, 8 Nov. 1972, *E.N.S.Jackson 2292* (HO).

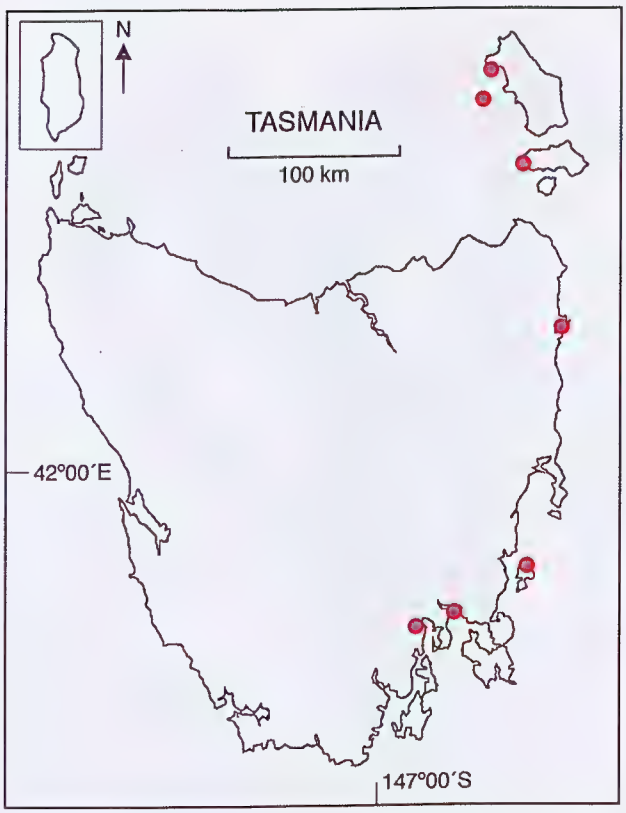

FIG. 3 — Geographical distribution of *Gomphocarpus fruticosus* as known from herbarium specimens.

TAXA NOT CONSIDERED NATURALISED IN TASMANIA

5. *Veronica peregrina* L., *Sp. Pl.* 1: 14 (1753) (Scrophulariaceae)

Common name: Wandering Speedwell

Illustrations: Richardson *et al.* (2011: 421); Briggs & Barker (1999: fig. 99h).

Discussion: This species is known in Tasmania from only two specimens (one attributed to F. Mueller (undated) and the other to C. Stuart in 1849), held at the National Herbarium of Victoria (MEL). The species is mentioned in Rodway's 1903 *Flora of Tasmania* as being "introduced from Europe". It is treated in *The Students Flora of Tasmania*

(Curtis 1967) with the note that it is "Introduced. Occasional in cultivated ground". Consequently it has been included as a sparingly naturalised species in the *Tasmanian Vascular Plant Census* (see de Salas & Baker 2015 and previous editions). Examination of the specimens revealed that they look identical in form and state of maturity and are therefore likely to be duplicates. In addition, it is known that Mueller and Stuart corresponded and that Stuart sent plant specimens that he collected in Tasmania to Mueller in South Australia (Home *et al.* 1998). Examination of all herbaceous *Veronica* specimens in the Tasmanian Herbarium collection revealed no specimens of *V. peregrina* misidentified amongst the other species. From this and the lack of notes accompanying the specimens, it is difficult to determine the status of this species in Tasmania. Having not been collected in the state for over 165 years strongly suggest that it is no longer present.

Veronica peregrina is a perennial herb, native to North and South America. It is widely naturalised throughout the world where it favours moist habitats including wastelands, pastures, river flats and creek margins. There are two subspecies: the glandular hairy taxon is *V. peregrina* subsp. *xalapensis* (Kunth) Pennell, whereas the glabrous taxon (illustrated in Richardson *et al.* (2011)) is the type subspecies. It is the hairy subspecies that is present as a naturalised plant in Australia where it is widespread in South Australia, Australian Capital Territory, New South Wales and Victoria. In Australia, it grows in similar habitats to where it is native, favouring moist and seasonally inundated environments in inland areas.

Specimens examined: **TASMANIA**: V.D.L. [Van Diemensland], *F.Mueller s.n.* (MEL2256541). *Tasmanian Northern Midlands (TNM)*: Woodhall. South Esk Riv[er]. Van Diemensland, Feb. 1849, *C.Stuart 459* (MEL).

6. *Silene colorata* Poir., *Voy. Barbarie* ii: 163 (1789). (Caryophyllaceae)

Synonym: Silene longicaulis auct. non Pourr. ex. Lag. *sensu* de Salas & Baker, *Tasmanian Vascular Plant Census* (2015).

Common name: Mediterranean Catchfly

Illustrations: Talavera (1990: Lám. 89a-g); Adams (1996: Fig. 51f)

Discussion: The inclusion of *Silene longicaulis* in the Tasmanian Vascular Plant Census (de Salas & Baker 2015) was based on a single specimen of *S. colorata* held at the National Herbarium of New South Wales (NSW). The specimen was recently discovered to have been misidentified as *S. longicaulis* after it was compared to other collections of *Silene* held at the Tasmanian Herbarium. This species is known in Tasmania from only two specimens (one attributed to F.A. Rodway and the other to L. Rodway) both collected from South Arm in the South East region. Examination of all *Silene* specimens in the Tasmanian Herbarium collection revealed no further specimens of *S. colorata*. From this and the lack of notes accompanying the specimens, it is difficult to determine the status of this species in Tasmania. However, having not been collected or recorded in the state for over 110 years strongly suggests that the species is no longer present.

Distribution and habitat: *Silene colorata* is an annual herb native to the Mediterranean region. In Australia, it has been recorded only in Tasmania.

Specimens examined: **TASMANIA**: *Tasmanian South East* (TSE): South Arm, 12 Feb. 1899, *F.A.Rodway 658* (NSW); South Arm, Dec. 1905, *L.Rodway 65A* (HO).

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REFERENCES

Adams, L.G. 1996: Caryophyllaceae. *In* Walsh, N. G. & Entwisle, T. J. (eds): *Flora of Victoria, Volume 3*. Inkata Press, Melbourne: 228–271.

Baker, M.L. 2005: Contributions to a catalogue of alien plants in Tasmania I. *Papers and Proceedings of the Royal Society of Tasmania* **139**: 33–48.

Baker, M.L. 2007: Contributions to a catalogue of alien plants in Tasmania II. *Papers and Proceedings of the Royal Society of Tasmania* **141**(2): 187–196.

Baker, M.L. 2011: Contributions to a catalogue of alien plants in Tasmania III. *Papers and Proceedings of the Royal Society of Tasmania* **145**: 27–34.

Briggs, B.G. & Barker, W.R. 1999: *Veronica. In* Walsh, N. G. & Entwisle, T. J. (eds): *Flora of Victoria, Volume 4. Cornaceae to Asteraceae*. Inkata Press, Melbourne: 509–516

Buchanan, A.M. 2005: *A Census of the Vascular Plants of Tasmania and Index to 'The Student's Flora of Tasmania', Fourth Edition, Tasmanian Herbarium Occasional Publication No. 7*. Tasmanian Museum and Art Gallery, Hobart: 108 pp.

CHAH-APC 2016: Australian Plant Census. Council of Australasian Heads of Herbaria. https://biodiversity.org.au/nsl/services/apc (accessed 15 June 2016).

CHAH-AVH 2016: *Australia's Virtual Herbarium*. Council of Australasian Heads of Herbaria. http://avh.chah.org.au/ (accessed 8 September 2016).

Curtis, W.M. 1967: *The Student's Flora of Tasmania, Part 3, Angiospermae: Plumbaginaceae to Salicaceae*. St David's Park Publishing, Hobart: 661 pp.

de Salas, M.F. & Baker, M.L. 2015: *A Census of the Vascular Plants of Tasmania, Including Macquarie Island, 2015 Edition*. Tasmanian Herbarium, Tasmanian Museum and Art Gallery, Hobart: 148 pp.

Duretto, M.F. 2009: Introduction, version 2009:1. *In* de Salas, M.F. & Duretto, M.F. (eds): *Flora of Tasmania Online*. Tasmanian Herbarium, Tasmanian Museum & Art Gallery: Hobart. ISBN 978-1-921599-45-3 (PDF). www.tmag.tas.gov.au/floratasmania (accessed 15 June 2016).

Forster, P.I. 1996: *Gomphocarpus. In* Orchard, A.E. & Wilson, A. (eds): *Flora of Australia, Volume 28*. CSIRO, Melbourne: 215–218.

Goyder, D.J & Nicholas, A. 2001: A revision of *Gomphocarpus* R.Br. (*Apocynaceae: Asclepiadeae*). *Kew Bulletin* **56**(4): 769–836.

Harden, G.J. 1990: Phytolaccaceae *In* Harden, G.J. (ed.): *Flora of New South Wales, Volume 1*. University of New South Wales Press, Sydney: 175–177.

Harden, G.J. & Williams, J.B. 1992: Asclepiadaceae. *In* Harden, G.J. (ed.): *Flora of New South Wales, Volume 3*. University of New South Wales Press, Sydney: 525–537.

Hewson, H.J. 1984: Phytolaccaceae. *In* George, A.S. (ed.): *Flora of Australia, Volume 4*. Australian Government Publishing Service, Canberra: 1–5.

Holmgren, P.K., Holmgren, N.H. & Barnett, L. 1990: *Index Herbariorum. Part 1. The Herbaria of the World. Eighth Edition.* New York Botanical Garden, New York: 693 pp.

Home, R.W., Lucas A.M., Maroske, S., Sinkora, D.M. & Voigt, J.H. 1998: *Regardfully Yours: Selected Correspondence of Ferdinand von Mueller, Volume 1: 1840–1859.* European Academic Publishers, Bern: 842 pp.

Jacobs, S.W.L & Harden, G.J. 1990: Nyctaginaceae. *In* Harden, G.J. (ed.): *Flora of New South Wales, Volume 1.* University of New South Wales Press, Sydney: 185–188.

Jeanes, J.A. (1999) Asclepiadaceae. *In* Walsh, N.G. & Entwisle, T.J. (eds): *Flora of Victoria, Volume 4.* Inkata Press, Melbourne: 325–332.

Jessop, J.P. 1986a: Nyctaginaceae. *In* Jessop J.P. & Toelken H.R. (eds): *Flora of South Australia, Part 1, Fourth Edition.* South Australian Government Printing Division, Adelaide: 188–190.

Jessop, J.P. 1986b: Phytolaccaceae, *In* Jessop J.P. & Toelken H.R. (eds): *Flora of South Australia, Part 1, Fourth Edition.* South Australian Government Printing Division, Adelaide: 184.

Kubitzki, K., Kallunki, J.A., Duretto, M. & Wilson, P.G. 2011: Rutaceae. *In* Kubitzki, K. (ed.): *The Families and Genera of Vascular Plants, Volume 10.* Springer, Berlin & Heidelberg: 276–356.

Le Duc, A. 1995: A revision of *Mirabilis* section *Mirabilis* (Nyctaginaceae). *Sida* **16**(4): 613–648.

Mabberley, D.J. 2008: *Mabberley's Plant-Book; A Portable Dictionary of Plants, their Classification and Uses, Third Edition.* Cambridge University Press, Cambridge: 1021 pp.

Marchant, N., Wheeler, J.R., Rye, B.L., Bennett, E.M., Lander, N.S. & Macfarlane, T.D. 1987: *Flora of the Perth Region, Part 1.* Western Australian Herbarium, Perth: 576 pp.

Nowicke, J.W. 1968: Palynotaxonomic study of the Phytolaccaceae. *Annals of the Missouri Botanical Garden* **55**(3): 294–363.

Paczkowska, G. & Chapman A.R. 2000: *The Western Australian Flora: a Descriptive Catalogue.* Wild Flower Society of Western Australia, Perth: 652 pp.

Parsons, W.T. & Cuthbertson, E.G. 2001: *Noxious weeds of Australia, 2nd Edition.* CSIRO Publishing, Collingwood: 698 pp.

Philips, R. & Rix, M. 2002: *The Botanical Garden, Volume 1, Trees and Shrubs.* Macmillan, London: 491 pp.

Richardson, F.J., Richardson R.G. & Shepherd R.C.H. 2006: *Weeds of the South-East: An Identification Guide for Australia.* R.G. Richardson and F.J. Richardson, Meredith: 438 pp.

Richardson, F.J., Richardson R.G. & Shepherd R.C.H. 2011: *Weeds of the South-East: An Identification Guide for Australia, Second Edition.* R.G. Richardson and F.J. Richardson, Meredith: 546 pp.

Rodway, L. 1903: *The Tasmanian Flora.* Government Printer, Hobart: 320 pp.

Spencer, R. 1997: *Horticultural Flora of South-Eastern Australia, Volume 2: Flowering Plants, Dicotyledons, Part 1.* University of New South Wales Press, Sydney: 606 pp.

Spencer, R. 2002: *Horticultural Flora of South-Eastern Australia, Volume 4: Flowering Plants, Dicotyledons, Part 3.* University of New South Wales Press, Sydney: 534 pp.

Talavera, S. 1990: *Silene. In* Castroviejo, S., Laínz, M., López González, G., Montserrat, P., Muñoz Garmendia, F., Paiva, J. & Villar, L. (eds): *Flora Iberica Volume. 2, Platanaceae-Plumbaginaceae (partim).* Real Jardin Botanico, Madrid: 313–406.

The Government of South Australia 2016: Electronic Flora of South Australia, Species Fact Sheet: *Phytolacca octandra,* http://www.flora.sa.gov.au/cgi-bin/speciesfacts_display.cgi?form=speciesfacts&name=Phytolacca_octandra (accessed 7 September 2016).

Walsh, N.G. 1996: Phytolaccaceae. *In* Walsh, N.G. & Entwisle, T.J. (eds): *Flora of Victoria, Volume 3.* Inkata Press, Melbourne: 101–102.

Wheeler, J.R., Marchant, N.G. & Lewington, M. (2002), *Flora of the South West, Volume 2.* ABRS, Canberra: 790.

Williams, I. 1981: Studies in the genera of the Diosmeae (Rutaceae): 9. A revision of the genus *Coleonema. Journal of South African Botany* **47**(1): 63–102.

Wilson, A.J.G. 2013: *Coleonema. In* Wilson, A. (ed.): *Flora of Australia, Volume 26.* ABRS/CSIRO Australia, Melbourne: 494–495.

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ODOARDO BECCARI AND ENRICO D'ALBERTIS IN AUSTRALIA AND NEW ZEALAND, 1878: BOTANICAL AND ZOOLOGICAL COLLECTIONS

by John Leslie Dowe

(with two text-figures, three plates, one table and two appendices)

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Though acclaimed for his scientific exploration and botanising in Borneo, New Guinea and Sumatra, Odoardo Beccari travelled briefly through Australia and New Zealand between 19 January and 5 April 1878. During this time, Beccari was in the company of navigator and ethnologist Captain Enrico Alberto D'Albertis. Although primarily a leisure tour, Beccari and D'Albertis engaged in botanical and zoological collecting when circumstances allowed. Specimens were collected in Queensland at Percy Islands and the Brisbane Botanic Garden; in New South Wales at the Blue Mountains; in Tasmania at Launceston, Corra Linn, Mount Wellington and Huon Road and in New Zealand at Bluff, Napier, Moeraki and Titirangi. Of the Australian and New Zealand specimens that have been located, the main life-form is bryophytes, with about 46 taxa of which 11 were described as new based on their collections. Only 13 herbarium specimens of vascular plants have been located and two of these were described as new taxa and represent type specimens. Of the zoological collections, about 20 ant (Formicidae) specimens were collected of which three were described as new taxa. Also collected were two specimens of earthworms (Lumbricidae), both of which were described as new, and three crustaceans (Amphipoda), two of which were described as new. This paper outlines their travel itinerary, provides a critical assessment of the collections, and examines the collaboration between Beccari and Baron Ferdinand von Mueller, Victorian Government Botanist at the time.

Key Words: Arecaceae, Australia, botanical and zoological collections, bryophytes, Captain Enrico D'Albertis, Ferdinand von Mueller, Formicidae, New Zealand, Odoardo Beccari, Tasmania.

INTRODUCTION

The visit of Odoardo Beccari and Captain Enrico D'Albertis to Australia and New Zealand in 1878 is a somewhat forgotten episode in the history of botany and zoology of these countries. Born on 16 November 1843 in Florence, Italy (died 25 October 1920, Florence), Beccari (pl. 1) was one of the most productive and influential botanists/naturalists of his era to work and collect in the biogeographical region of Malesia, an area extending from Sumatra in the west to the Philippines in the north and east to New Guinea (Beccari 1924, van Steenis-Kruseman 1950, Pichi-Sermolli & van Steenis 1983, Chazdon & Cranbrook 2002). Between 1865 and 1878, Beccari made large collections of botanical, entomological, ethnographic, ornithological and zoological specimens which he remitted to scientific institutions in Italy, mainly the Museo di Storia Naturale dell'Università di Firenze (van Steenis 1952, Clauser *et al.* 2013, Andreone *et al.* 2014) and the Museo Civico di Storia Naturale di Genova (Doria 2010, Clouse & Giribet 2012). Beccari's Malesian collections were studied by various specialists, and many thousands of new taxa were based on his specimens. The botanical collections were primarily worked on by Beccari himself at the Università di Firenze, where he maintained the herbarium (Cuccuini 2009), and the results were written up in journals that he established, such as the *Nuovo Giornale Botanico Italiano,* 1869–1871, and *Malesia*, 1877–1883 (Nepi 2009). Other significant monographs and papers, particularly on palms, were later published in journals such as *Webbia, Annales du Jardin Botanique de Buitenzorg, Annals of the Royal Botanic Garden, Calcutta* and *The Philippine Journal of Science* among others. From about 1880, he directed his attention almost solely to the study of palms (Arecaceae), and established the world's largest and most important palm herbarium at Florence (Cuccuini & Nepi 2006). Many biographical sketches have been prepared on Beccari (Burkill & Moulton 1921, Jackson 1922, Pollacci 1935, Biagioli 2005, George 2009), and portray him as a brilliant, productive, single-minded "complete" scientist but a somewhat impulsive, impatient and misanthropic individual particularly in later life (Moore 1981, Cuccuini & Nepi 2006).

Beccari's travelling companion during the Australian and New Zealand journey was Captain Enrico Alberto D'Albertis (born 23 March 1846, Voltri, Italy; died 3 March 1932, Genoa, Italy) (pl. 2), retired Italian Navy Officer, navigator, writer, philologist, ethnologist and philanthropist (Orlandi 2009). Captain D'Albertis was the cousin of Count Luigi Maria D'Albertis, the renowned explorer, ethnologist, and botanical and zoological collector (D'Albertis 1880, Gnecchi-Ruscone 2011). As a result of his travels throughout the world, Captain D'Albertis established a significant collection of ethnographic and maritime artefacts (Fornaroli 1935), as well as marine animal, algae and plant specimens (Nizamuddin *et al.* 1978, Capocaccia & Poggi 1982). His navigational pursuits took him around the world three times (including a second visit to New Zealand in 1896 and to Australia in 1910), a circumnavigation of Africa and a re-enactment of the voyage of Christopher Columbus to San Salvador Island using instruments modelled on those of the original voyage (Fornaroli 1935, De Pascale 2008, 2009).

PLATE 1 — Odoardo Beccari, 9 February 1878, *carte-de-visite* by John William Lindt, Melbourne. Presented to Julius van Haast, 4 March 1878. From the Haast Family collection [PA–0132], Alexander Turnbull Library, Wellington, New Zealand.

PLATE 2 — Enrico Alberto D'Albertis, 9 February 1878, *carte-de-visite* by John William Lindt, Melbourne. Presented to Julius van Haast, 4 March 1878. From the Haast Family collection [PA–0133], Alexander Turnbull Library, Wellington, New Zealand.

In 1886, D'Albertis began construction of the spectacular Castello di Montegalletto in Genoa in the Gothic revival style, firstly to be used as his home and, secondly, to store and display his ethnographic and maritime collections. Upon his death in 1932, the castle was donated to the city of Genoa and renamed Castello D'Albertis (Surdich 1985), and since 2004 has been operating as the Museo delle Culture del Mondo (De Palma 2008).

Unlike the extensive documentation of Beccari's Malesian explorations, little has been written about his activities and collecting pursuits in Australia and New Zealand. Despite this, some important collections were made of bryophytes, ants, earthworms, crustaceans and vascular plants, and amounting to about 84 known specimens. Beccari and D'Albertis were also active in visiting botanic gardens and museums in Australia and New Zealand, and engaging and socialising with botanists, naturalists, statesmen and politicians. The collaboration between Beccari and Baron Ferdinand von Mueller, Government Botanist of Victoria, deserves special attention, as they worked together on the New Guinea flora, but met for the first, and only, time during Beccari's visit to Melbourne.

METHODS

The personal diaries of both Odoardo Beccari and Captain Enrico D'Albertis were made available from library and museum collections in Italy. They were translated either by the author or with assistance from Anna Giulia D'Albertis, great grandniece of Enrico D'Albertis. Quotes from the diaries are included verbatim (in English) and author additions or comments are included in brackets. Correspondence items were accessed through the Mueller Correspondence Project, Royal Botanic Gardens Victoria, the Royal Botanic Gardens Kew archives, the Science Library in the University of Florence and the Alexander Turnbull Library, Wellington, New Zealand. Quotes from letters are included verbatim, and author additions and comments are included in brackets. The specimens they collected were located through herbarium and museum databases, as well as the scientific literature associated with the results of research carried out on their collections, mostly accessed through the Biodiversity Heritage Library online facility. Taxonomy and nomenclature of Australian plants follows the *Australian Plant Name Index* (www.anbg.gov.au) and for New Zealand plants the *Flora of New Zealand* (floraseries.landcareresearch.co.nz); bryophyte taxonomy

follows *AusMoss* (data.rbg.vic.gov.au); ant taxonomy follows the *Atlas of Living Australia* (bie.ala.org.au) and *AntWeb* (www.antweb.org); and earthworms follow *ITIS Report* (www.itis.gov). It was beyond the scope of this paper to comment on the taxonomic and nomenclatural validity of the species and the names that are herein annotated, but rather they are presented as a record of the collections that Beccari and D'Albertis made during their travels in Australia and New Zealand.

EXPLORATION

The Australian and New Zealand journey was part of the third extended excursion to be undertaken by Beccari to the "East". Previously, he had carried out two major collecting expeditions in Malesia (Ballard 2009). The first, from April 1865 until March 1868, was in Borneo in what is now Brunei and Sarawak. The second, from January1871 to June 1876, proceeded through the Sunda Islands, and western New Guinea, the present-day Indonesian provinces of Papua and West Papua (Lydon 2014). The third expedition, the one which is in part the subject of this paper, ran from October 1877 to December 1878. The travel route through Australia (19 January to 23 February and 17 March to 5 April 1878) is shown in figure 1, and that through New Zealand (26 February to 12 March 1878) in figure 2. An annotated itinerary for Australia and New Zealand is given in appendix 1.

Although their original intention was to travel around the world together (Anon. 1877), Beccari and D'Albertis parted company about six months into the 12-month venture. When they returned to Singapore in mid-April 1878, after completing the Australian and New Zealand sections of the voyage, D'Albertis continued on to Hong Kong, China, Japan, the United States, Panama and Peru before returning to Genoa in October 1878 (D'Agnese 2007). Meanwhile, Beccari remained in Indonesia (then Dutch East Indies), at first visiting Java where he stayed at the Buitenzorg Gardens (Kebun Raya Bogor) (1–29 May), before travelling to southern and western Sumatra (30 May–22 October) where he remained for five months making extensive botanical and zoological collections, particularly in the Mount Singalang area (Cora 1880). It is during this time that Beccari made some of his most notable botanical discoveries, including the giant aroid *Amorphophallus titanum* (Becc.) Becc. ex Arcang. (Titan arum), a species with which Beccari has become singularly associated (Hooker 1891, Gandawijaja *et al.* 1983). He departed Sumatra on 22 October and arrived back in Florence in December 1878.

Beccari's itineraries, collections and travelling routes in Malesia are well-documented, as he kept thorough notes, detailed specimen information and produced field illustrations and maps (Capocaccia & Poggi 1982, Graniti 2004). These data were supported by a number of books, including two autobiographical works that dealt with his own explorations (Beccari 1904, 1924), and others written by his early travelling companions, the naturalist Giacomo Doria (Doria 1878) and the explorer/naturalist Count Luigi Maria D'Albertis (D'Albertis 1880). Beccari is renowned for the high quality of his specimens and his enduring taxonomy and nomenclature (Cuccuini & Nepi 2006).

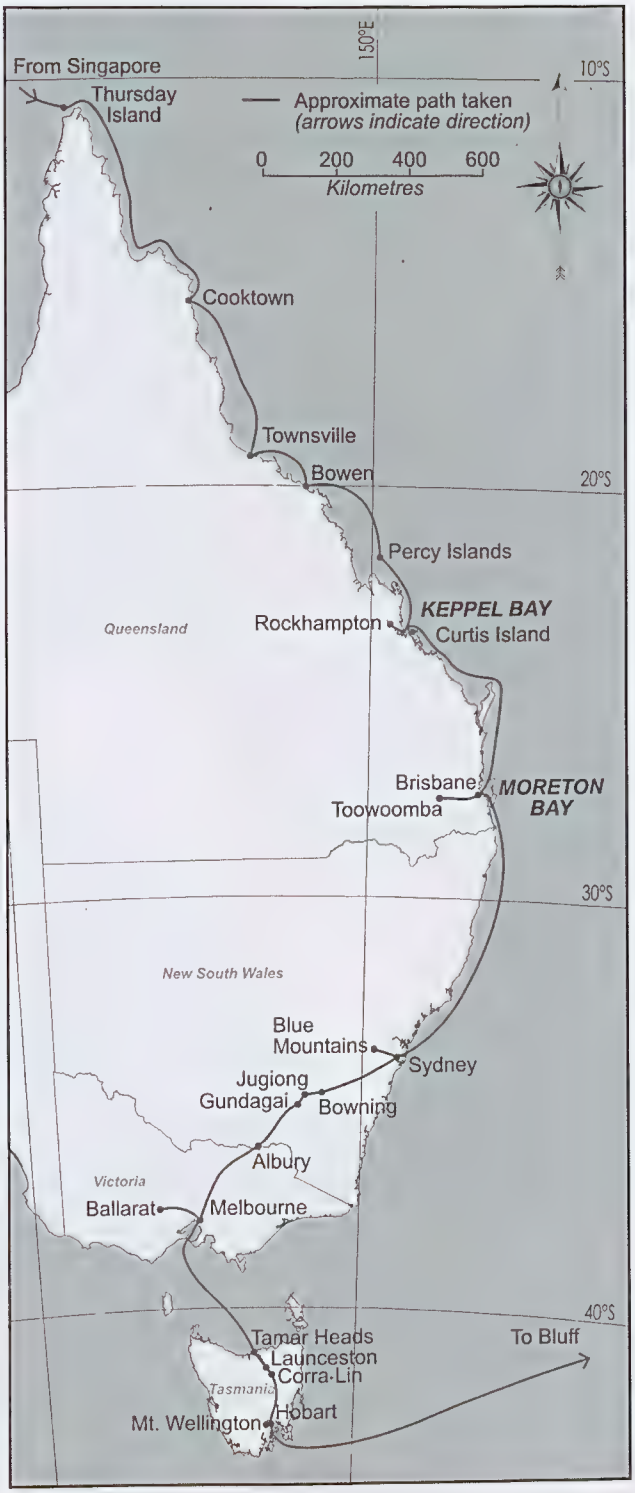

FIG. 1 — Route taken by Odoardo Beccari and Captain Enrico D'Albertis through eastern Australia, 19 January to 5 April 1878. Map prepared by Claire Burton, Cairns Regional Council.

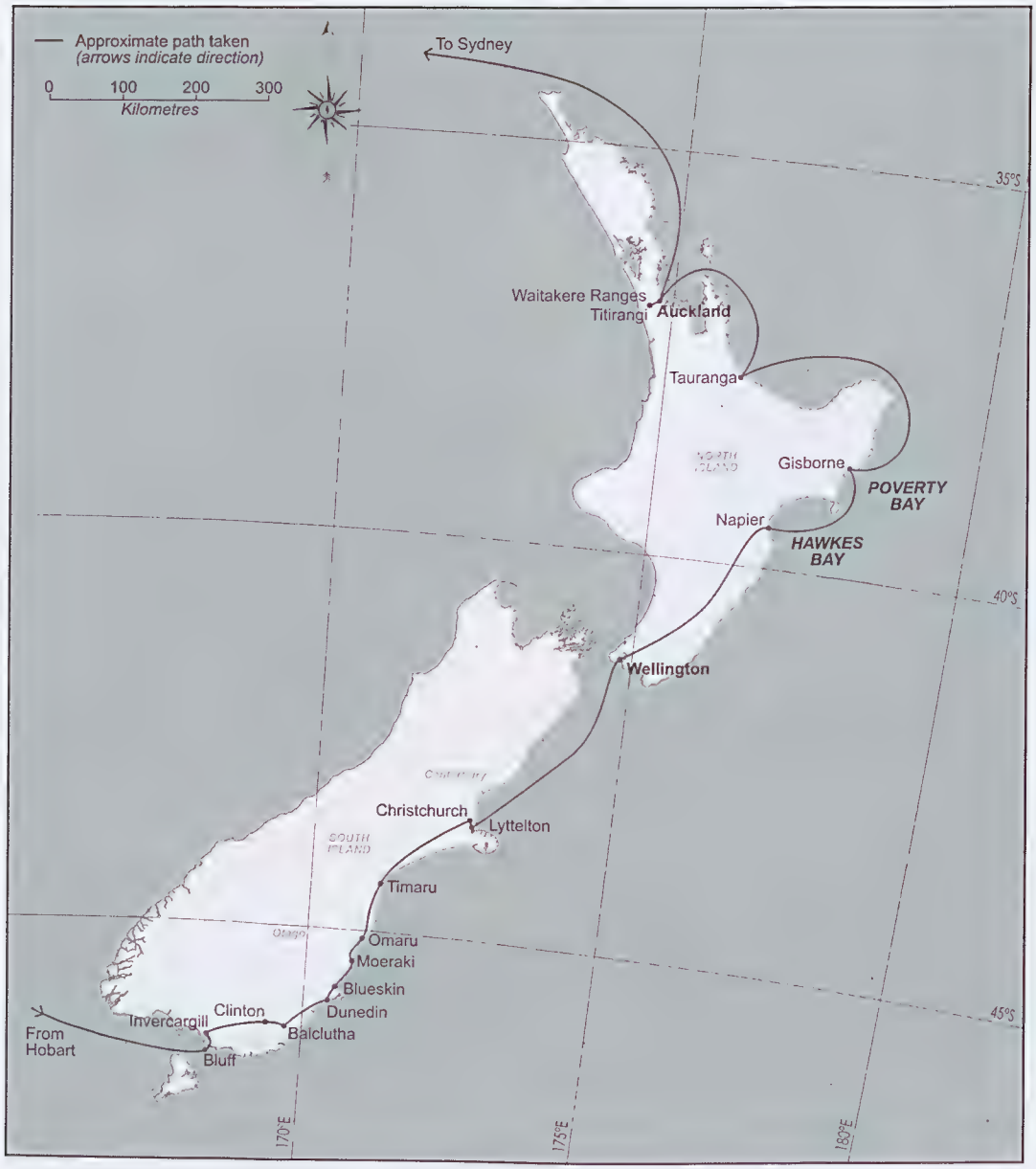

FIG. 2 — Route taken by Odoardo Beccari and Captain Enrico D'Albertis through New Zealand, 26 February to 12 March 1878. Map prepared by Claire Burton, Cairns Regional Council.

SUMMARY OF COLLECTIONS

Although the visit of Beccari and D'Albertis to Australia and New Zealand in 1878 is unfamiliar to most contemporary botanists and zoologists in these two countries, they made important collections that were mostly returned to institutions in Europe. There the specimens were studied by specialists in various fields and new species were described and published. The specimens collected in Australia and New Zealand included bryophytes (46 specimens) and ants (20), with lesser numbers of vascular plants (13), crustaceans (three) and earthworms (two): a total of 84 specimens (appendix 2). The most significant collections were made in Tasmania on Mount Wellington on a single day (19 February 1878) when almost 40 specimens of bryophytes, two new species of crustaceans, and a new species of earthworm, were collected.

The first publication relating to the collections was an annotated list of 39 bryophytes by Hampe & Geheeb (1881) based on the Beccari collections from Tasmania and New Zealand. This work included four new species. The herbaria to which Beccari sent the bryophytes were not recorded, although it can be suspected that they were first received by the Herbarium Universitatis Florentinae and later distributed from there. Geheeb, one of the authors of that publication, maintained a large personal herbarium in Jena, Germany, which was eventually transferred to the Botanischer Garten und Botanisches Museum Berlin-Dahlem (Sayre 1977). Historical citation data listed some of Beccari's Australian and New Zealand collections as being in the "Herb. Geheeb", so it is assumed that some specimens or duplicates were sent to Geheeb, although no independent documentation of this has been located because of the dismantling and loss of Geheeb's herbarium after his death in 1909 (Sayre 1977). Later, Carl Müller, who also maintained a private herbarium that was similarly donated to the Botanischer Garten und Botanisches Museum Berlin-Dahlem, studied the Beccari collections, and described an additional seven new species (Müller 1897). The bryophyte collection at Berlin was unfortunately devastated during a bombing raid in the Second World War in 1943, thus destroying many type

specimens and introducing subsequent problems relating to typification and taxonomy (Isoviita & Ochyra 1990, Ramsay 2006). Some specimens are also cited as being in the "Hb. Levier", the private herbarium of Emilio Levier, a Swiss-born physician and botanist who resided in Florence; his collection is now held in the Herbarium Universitatis Florentinae [FI].

There is evidence that some of Beccari's Australian and New Zealand bryophyte specimens were distributed prior to the 1940s as they have been located, for example, in the herbaria of the University of Tennessee [TENN], New York Botanical Gardens [NY], Royal Botanic Gardens Sydney [NSW], the Finnish Museum of Natural History, University of Helsinki [H-BR] and the Natural History Museum, London [BM]. As far as it has been possible to investigate, at least 11 new bryophyte taxa were described from specimens collected by Beccari in Australia and New Zealand. This is a relatively high rate considering there were about 46 specimens collected in total, and this is probably not so much a function of the range of specimens collected, but a reflection of the active research on Australian and New Zealand bryophytes at that time and that broad collections were bound to yield novelties. Eponymous taxa, described mostly from bryophyte specimens collected by Beccari and D'Albertis in Australia, are presented in table1.

The ultimate fate of the ant specimens is better known than that of the bryophytes as they were deposited directly into the Museo Civico di Storia Naturale di Genova [MSNG] where they remain today. The collections were studied by Emery (1886, 1887) who described three new taxa, one from the Percy Islands and two from the Blue Mountains (appendix 2), of which two, one from each location, represented new subspecies and the other, from the Blue Mountains, a new species. Unlike the bryophytes which were recorded with Beccari as the sole collector, the ants were all recorded with both Beccari and D'Albertis as co-collectors. D'Albertis was later to note that Beccari's main interest during the Australian and New Zealand journey was to make botanical and zoological collections, and that he, Beccari, had shown uncharacteristic patience and restraint when he was required to attend to travel tasks and social events rather than venture into the local areas to collect specimens. Beccari nevertheless recorded D'Albertis as a co-collector for many specimens, for which D'Albertis was apparently grateful (Fornaroli 1935).

Two earthworms, in the genus *Megascolides*, were collected, one each from Tasmania and New Zealand (appendix 2), and both were described as new species by Cognetti de Martiis (1910). Three crustacean specimens, amphipods in the genus *Talitrus*, were collected from Mount Wellington, Tasmania, of which two were described as new species by Ruffo (1949). As with the ant specimens, the earthworms and crustaceans were sent to the Museo Civico di Storia Naturale di Genova [MSNG] where many of the specimens are extant. One of the amphipods was later redescribed as a new taxon under a different name by Friend (1987) although the validity of such a proposal is doubtful (appendix 2).

Considering that Beccari's primary research interests involved vascular plant taxonomy, the small number of vascular plant specimens that he collected in Australia and New Zealand is surprising. In total, only 13 herbarium specimens of vascular plants have been located (appendix 2). Seven of these were collected on the Percy Islands, and were the first collections made by the travellers in Australia. Six of these specimens were directly deposited at the time into von Mueller's Phytologic Museum of Melbourne, now the National Herbarium of Victoria, Royal Botanic Gardens Melbourne, and the seventh is at the Herbarium Universitatis Florentinae [FI]. Three vascular plant specimens were collected in Tasmania, of which two represented type specimens (Bitter 1910), and one in New Zealand. Two cultivated specimens of palms were collected from the Brisbane Botanic Gardens (appendix 2), and these are now in the Herbarium Universitatis Florentinae (Cuccuini & Nepi 2006). The vascular plant specimens were all recorded with Beccari as the sole collector. For some specimens collected on Mount Wellington, purpose-printed labels were prepared with the wording "*Piante del viaggio esequito nell'anno 1878*

TABLE 1 — Eponymous taxa named for Odoardo Beccari and Enrico D'Albertis, based on species described from specimens they collected in Australia and New Zealand, 1878.

Taxon	Publication
MOSSES	
Bryum beccarii Müll.Hal. [*Pohlia nutans* (Hedw.) Lindb.], Tasmania. Mt Wellington, 19 Feb. 1878, *Beccari s.n.*	*Hedwigia* 37: 87 (1898).
Leptotheca beccarii Müll.Hal. [*Leptotheca gaudichaudii* Schwägr.], Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 22*; lectotype: FI; isolectotype: NY00913954.	*Gen. Musc. Frond.* 148 (1901).
Mniadelphus beccari Müll.Hal. [*Distichophyllum rotundifolium* (Hook.f. & Wilson) Müll.Hal. & Broth.]. Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari s.n.*	*Rev. Bryol.* 8: 27 (1881).
Polytrichum beccarii Müll.Hal. [*Polytrichum juniperinum* Hedw.], Tasmania, Mt Wellington, 19 Feb, 1878, *Beccari s.n.*: isotype: H-Br.	*Hedwigia* 36: 345 (1897).
EARTHWORM	
Megascolides albertisii (Cognetti de Martiis, 1910) [*Aporodrilus albertisii* (Cognetti de Martiis, 1910)], Tasmania, Mt Wellington, 19 Feb, 1878, *E.D'Albertis & Beccari s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova* ser. 3, 44: 329 (1910).

The original name appears first, and the current name follows in brackets. Collection date is determined from travel itinerary. Location of specimens is given where known.

PLATE 3 — Ferdinand von Mueller, circa 1877, *carte-de-visite* by John Botterill, Melbourne, presented to Captain Enrico D'Albertis during his visit to Melbourne. With permission of the Settore Musei e Biblioteche Comune di Genova.

– *Abita:- Sul Monte Wellington Tasmania*". It is most likely that other vascular plant specimens were collected, such as from the Blue Mountains in New South Wales, as was noted in D'Albertis' diary, but they have not been located, and further research is required, especially in the Herbarium Universitatis Florentinae where full documentation of the collection has yet to be completed.

Apart from preserved plant specimens, it was noted by D'Albertis that seeds of plants were also collected, but there are no known associated herbarium specimens. For example, in New Zealand, they collected seeds of a number of plants during an overland section of their coach journey between Dunedin and Moeraki, including the New Zealand Cabbage Tree *Cordyline australis* (Forst.f) Hook.f., 'Ombrellaria' (possibly *Schefflera digitata* J.R.Forst. & G.Forst.) and the Nikau palm *Rhopalostylis sapida* (Sol. ex G.Forst.) H.Wendl. & Drude (Fornaroli 1935). Beccari was known to have grown plants, in the Orto Botanico di Firenze, that he had collected elsewhere. However, there is no evidence in the plant and seed exchange or cultivated plant lists that any propagation materials or live plants related to those plants collected in Australia or New Zealand were either being cultivated or available for exchange (Mattirollo 1897, Aiuti 1901).

FERDINAND VON MUELLER AND ODOARDO BECCARI

In the years prior to Beccari's first personal meeting with Ferdinand von Mueller (pl. 3) in Melbourne, the two had exchanged correspondence and publications, and had collaborated on von Mueller's *Descriptive Notes on Papuan Plants* (von Mueller 1875–1877). The first few parts of that publication were based on specimens collected by Count L. M. D'Albertis and Andrew Goldie in the southeastern part of New Guinea and sent directly to von Mueller in Melbourne. Subsequent parts were based on Beccari's collections from northwest New Guinea. Those specimens were at first returned to Florence from where duplicates were later sent to von Mueller in Melbourne. The work on Papuan plants was outlined by von Mueller (1877) in a letter to Beccari, in which he stated that:

> *[31 December 1877] When returning from a phytographic excursion to Shark-Bay and other portions of West-Australia, dear Dr Beccari, I received your kind letter of the 10th September, to which I now briefly reply on board of the Steamer on my route to Melbourne. I received your valuable first part of the publication on Melanesian plants, for which I owe you my best thanks. What a flood of light that work will shed on New Guinea and the neighbouring islands! My "Papuan plants" will be more an account of the S. E. vegetation, while your work will more particularly refer to the N. W. ...If you desire for comparison any Australian species of Indian genera, I will forward them to you through the Italian Consulate. ...You can have besides extensive collections of Australian plants, if you will kindly let me have duplicates of yours when finally you come to distribute them.*

After their meeting in Melbourne in 1878, their exchange of correspondence became more detailed with regard to botanical activities. In response to a letter written by Beccari soon after he departed Australia and which he had posted at Singapore, von Mueller (1878a) noted a number of botanical items:

> *[1 June 1878] It was very pleasing to me, dear Dr Beccari, to get your kind letter from Singapore, dated 19 April. Let me hope, that you will find your position in Florence amidst your riches & treasures, congenial to your tastes! What a path of glory have you before you! As regards Signor D'Albertis's [Count Luigi Maria D'Albertis] plants, I shall of course be grateful for any, which you can spare me. I met D'Albertis here for two days, which was a source of great pleasure to me. He left a few living plants, which will likely come under my cognizance, when in flower. Australia is almost exhausted, so far as new plants are concerned. Hence I must rely on New Guinea or some other part of the globe for novelties. It is quite likely, that I mistook a* Platea *for a* Lasianthera *or* Gomphandra, *as I had not*

the benefit of using your excellent memoir on Olacineae, when I worked out the only Australian species as yet known. I will send you a specimen.

Disappointed with some aspects of their meeting in Melbourne, von Mueller (1878b) confided in William Thiselton-Dyer, Director of Kew Gardens, about this and wrote that:

I had a visit from Dr Beccari; what a humiliation of the "Princeps of Australian Botany" (as you considerately call me) to be obliged to tell the Director of the Botanic Garden of Florence, that his colleague here was a nurseryman, and that I could not set my foot into my own garden since 5 years with any self-respect.

Appointed Director of the Melbourne Botanic Gardens in 1857, von Mueller held the position until 1873 when he was controversially "relieved" of the directorship. His scientifically orientated garden designs and layouts were considered, both publicly and by government officials, not to have been providing appropriate "ornamental" character for such a prominent public facility and his official responsibilities were rewritten to exclude him from the botanic gardens management but to maintain him as Government Botanist (Cohn & Maroske 1996).

Later, in a subsequent letter from von Mueller (1879) to Beccari, there was evidence of an increasing interest in the palm family:

[5 April 1879] Herewith, dear Dr Beccari, I send you the fruits of a new Areca *from Trinity Bay [*Areca alicae *F.Muell.]. The species is allied to* A. triandra *&* A. oxycarpa. *I have sent the description to Dr von Regels Garten-Flora. Let me thank you for the splendid 3rd fascicle of the Malesia! In what treasures you are revelling!! I quite envy you about your Rhododendrons &c.*

Beccari's visit to Melbourne encouraged von Mueller to send an increasing number of palm specimens to Beccari who had seemingly been "assigned" by him as the primary taxonomic investigator of Australian palms. Subsequently, von Mueller (1887) wrote to Beccari stating that:

*[10 March 1887] I have put a few specimens of Australian palms together for you, dear Dr Beccari, such as recently were obtained, but — as you will be aware — these noble plants occur but very scantily in this part of the world. There is a new one among them, collected on the Bloomfield River by Miss Ellie Bauer to whom I should like it dedicated [*Livistona humilis *var.* sclerophylla *Becc.* = L. muelleri *F.M. Bailey]. The young lady just lost her father through death, so this naming of a palm in honor of herself, will cheer her in the present sorrow. According to departmental entries here, you received some years ago of all palms of Australia, so far as they are contained in my museum, fragments of leaves flowers and fruit, wherever such could be spared; but the material in my museum is now very limited, after Drude, Wendland & Kew were supplied. Lord Howe's Island is rarely visited, and it is not easy to obtain specimens from there. Wendland & Drude gave however a good account of the palms from that Island. I should be very glad, if you would early publish a description of Miss Ellie's palm, as so much competition has arisen, that such plant may easily fall into the hands of another Botanist.*

The last known letter from von Mueller to Beccari was sent in 1890 accompanying a palm specimen from New Guinea, and in which von Mueller (1890) noted that:

*[13 March 1890] By this mail, dear Dr Beccari, I have posted to you the only specimen of an only palm [*Heterospathe macgregorii *(Becc.) H.E. Moore], received from Sir William Macgregor among the dried plants, gathered by his Excellency on his tour up the Fly-River. Will you be so kind, to send a few fragments back for the Government Herbarium here, after you have examined the species. Three iron cylinders, filled with methylized alcohol, and sent for collecting purposes by me, will be this week emptied of the botanic specimens, contained therein. Should palms be among them they will be also sent to you.*

From Beccari's Papuan collections, von Mueller named one species to honour Beccari (*Myrtella beccarii* F.Muell. (= *Fenzlia beccarii* (F.Muell.) Burret), collected from Humboldt Bay (Yos Sudarso Bay, Papua) (Mueller 1875–77). He was later to name a second species to honour Beccari, the palm *Kentia beccarii* F.Muell. (= *Hydriastele montana* (Becc.) W.J.Baker & Loo) (Mueller 1880). Beccari was to return the eponymous favour, naming three new plant species to honour von Mueller: the epiphytic ant-plant *Myrmecodia muelleri* (F.Muell.) Becc., and two palms, *Normanbya muelleri* Becc. (=*Normanbya normanbyi* (W.Hill) L.H.Bailey) and *Ptychandra muelleriana* Becc. (=*Heterospathe muelleriana* (Becc.) Becc.).

SUMMARY

The visit of Beccari and D'Albertis to Australia and New Zealand has been somewhat overlooked by Australian and New Zealand scientists. Although their visit was primarily a leisure tour, they made some significant collections, in particular of bryophytes and ants. As their specimens were returned to institutions in Italy, there may have been some "cultural blockage" in such information becoming available to scientists in Australia and New Zealand. There was considerable collaboration between Beccari and Ferdinand von Mueller with regard to botanical research, but no other obvious collaboration with other Australian or New Zealand scientists has been identified. This paper has provided an overview of their travel itinerary and, as far as possible, has presented and annotated the various specimens that were collected by Beccari and D'Albertis in Australia and New Zealand.

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REFERENCES

Aiuti, L. 1901: *Elenco dei duplicati di piante secche offerte in cambio dal R. Istituto botanico di Firenze.* Luigi Niccolai, Firenze: 4 pp.

Andreone, F. , Bartolozzi, L., Boano, G., Boero, F., Bologna, M.A., Bon, M., Bressi, N., Capula, M., Casale, A., Casiraghi, M., Chiozzi, G., Delfino, M., Doria, G., Durante, A., Ferrari, M., Gippoliti, S., Lanzinger, M., Latella, L., Maio, N., Marangoni, C., Mazzotti, S., Minelli, A., Muscio, G., Nicolosi, P., Pievani, T., Razzetti, E., Sabella, G., Valle, M., Vomero, V. & Zilli, A. 2014: Italian natural history museums on the verge of collapse? *ZooKeys* **456**: 139–146.

Anon. 1877: Notes. *Nature: A Weekly Illustrated Journal of Science* **17**: 52–54.

Anon. 1879: *Report of the Royal Society of Tasmania for the Year 1878.* James Barnard, Hobart Town.

Ballard, C. 2009: The art of encounter: verisimilitude in the imaginary exploration of the interior of New Guinea, 1725–1876. *In* Jolly, M., Tcherkézoff, S. & Tryon, D.T. (eds): *Oceanic Encounters; Exchange, Desire, Violence.* ANU E Press, Canberra: 221–257.

Beccari, O. 1878a: *Australia con D'Albertis, 1877–1878.* Giornale delle spese 16. Biblioteca di scienze, Università degli Studi di Firenze. Unpublished manuscript.

Beccari, O. 1878b: Sulle piante raccolte alla Nuova Guinea dal. Sig. L.M. D'Albertis durante l'anno 1877, con descrizione di tre nouve specie di Icacineae. *Malesia* **1**: 255–257.

Beccari, O. 1904: *Wanderings in the Great Forests of Borneo: Travels and Researches of a Naturalist in Sarawak.* Archibald Constable, London: 424 pp.

Beccari, O. 1924: *Nova Guinea, Selebes e Molucche. Diari di Viaggio Ordinati dal Figlio Prof. Dott. Nello Beccari.* La Voce, Florence: 468 pp.

Biagioli, B. 2005: *L'Archivo Odoardo Beccari nella Biblioteca del Dipartimento di Biologia Vegetale Università degli Studi di Firenze,* www.sba.unifi.it/upload/scienze/inventaripdf/Archivo_Beccari.pdf (accessed November 2015).

Bitter, G. 1910: Die gattung *Acaena.* Vorstudium zu einer monographie. *Bibliotheca Botanica* **17**(74): 1–336.

Burkill, I. H. & Moulton, J.C. 1921: Odoardo Beccari. *Journal of the Straits Branch of the Royal Asiatic Society* **83**: 166–173.

Capocaccia, L. & Poggi, R. 1982: Short history of the Museo Civico di Storia Naturale "Giacomo Doria" in Genoa, Italy. *Archives of Natural History* **11**(1): 107–122.

Chazdon, R.L. & Earl of Cranbrook 2002: Tropical naturalists of the sixteenth through nineteenth centuries. *In* Chazdon, R.L. & Whitmore, T.C. (eds): *Foundations of Tropical Forest Biology: Classic Papers with Commentaries.* University of Chicago Press, Chicago: 5–14.

Clauser, M., Cecche, L., Grigioni, A. & Lombardini, C. 2013: L'azione degle orti botanici per l'introduzione di piante utili o scientificamente importanti. *Altre Modernità* **10–11**: 153–163.

Clouse, R. & Giribet, G. 2012: On the Cyphothalmi (Arachnida, Opiliones) types from the Museo Civico di Storia Naturale "Giacomo Doria". *Bulletin of the Museum of Comparative Zoology* **160**(5): 241–257.

Cognetti de Martiis, L. 1910: Nuove specie dei generi *Megascolides* e *Pheretima. Annali del Museo Civico di Storia Naturale di Genova* ser. 3(4) **44**: 327–334.

Cohn, H.M. & Maroske, S. 1996: Relief from duties of minor importance: the removal of Baron von Mueller from the directorship of the Melbourne Botanic Gardens. *Victorian Historical Magazine* **67**(247): 103–127.

Cora, G. 1880: Explorazioni di Beccari nell'ovest di Sumatra (1878). *Cosmos: Communicazioni sui Progressi piú Recenti e Notevoli della Geografia e delle Scienze Affini* **5**: 261–263.

Cuccuini, P. 2009: L'Erbario delle palme di Odoardo Beccari. *In* Raffaeli, M. (ed): *Il Museo di Storia Naturale dell'Università degli Studi di Firenze, Vol. 2, Le Collezioni Botaniche, Firenze*: Firenze University Press, Firenze: 133–152.

Cuccuini, P. & Nepi, C. 2006: The palms of Odoardo Beccari. *Quaderni di Botanica Ambientale e Applicata* **17**/1: 5–251.

D'Agnese, G. 2007: D'Albertis alla ricerca degli Hopi. *Magazine Domenicale di America Oggi,* 16 September 2007. www.oggi7.info (accessed November 2015).

D'Albertis, E.A. 1878: *Ciarpe, frastagli e scampoli.* Archivio Castello D'Albertis, Settore Musei e Biblioteche Comune di Genova. Unpublished manuscript.

D'Albertis, L.M. 1880: *New Guinea: What I Did and What I Saw.* 2 Volumes. S. Low Marston, Searle & Rivington, London: 424 pp & 406 pp.

De Palma, M.C. 2008: *Castello d'Albertis: Museo delle Culture del Mondo.* Silvana Editoriale, Milan: 80 pp.

De Pascale, A. 2008: Enrico Alberto D'Albertis: il finalese e la collaborazione con Arturo Issel. *In* De Pascale, A., Del Lucchese, A. & Raggio, O. (eds): *La Nascita della Paletnologia in Liguria: Personaggi, Scoperte e Collezioni tra XIX e XX Secolo, Atti del Convegno (Finale Ligure Borgo, 22–23 settembre 2006)*). Bordighera, Ligure: 337–346.

De Pascale, A. 2009: Enrico Alberto D'Albertis (1846–1932) e la sua collezione archeologica. *In* Gandolfi, D. & Venturino Gambari, M. (eds): *Colligite Fragmenta: Aspetti e Tendenze del Collezionismo Archeologico Ottocentesco in Piemonte, Atti del Convegno (Tortona, 19–20 gennaio 2007).* Bordighera, Ligure: 325–330.

Doria, G. [Giacomo] 1878: Naturalisti Italiani alla Nuova Guinea. *Bollettino della Società Geografica Italiana,* 2nd ser. **3**(15): 154–169.

Doria, G. [Giuliano] 2010: La collezione erpetological del Museo Civico di Storia Naturale "G. Doria" di Genova. *Museologia Scientifica Memorie* **5**: 62–68.

Emery, C. 1886: Catalogo delle formiche esistenti nelle collezioni del Museo Civico di Genova. Parte terza. Formiche della regione Indo-Malese e dell'Australia. *Annali del Museo Civico di Storia Naturale Giacomo Doria (Genova),* 2nd ser. 4(24): 209–258.

Emery, C. 1887: Catalogo delle formiche esistenti nelle collezioni del Museo Civico di Genova. Parte terza. Formiche della regione Indo-Malese e dell'Australia (Continuazione e fine). *Annali del Museo Civico di Storia Naturale Giacomo Doria (Genova),* 2nd ser. **4**(24): 427–473.

Fornaroli, L.A. 1935: *Enrico Alberto d'Albertis, 1846–1932: E un'Appendice sul Castello di Montegalletto.* Bozzo & Coccarello, Genova: 317 pp.

Friend, J.A. 1987: The terrestrial amphipods (Amphipoda: Talitridae) of Tasmania: systematics and zoogeography. *Records of the Australian Museum,* Supplement **7**: 1–85.

Gandawijaja, D., Idris, S. & Nasution, R. 1983: *Amorphophallus titanum* Becc.: a historical review and some recent observations. *Annals of Botany* **51**(3): 269–278.

George, A.S. 2009: *Australian Botanist's Companion.* Four Gables Press, Kardinya, Western Australia: 671 pp.

Gnecchi-Ruscone, E. 2011: From New Guinea 1872–78 to Genova 2004: recovering Luigi Maria D'Albertis' private collection. *Journal de la Société des Océanistes* **132**: 165–182.

Graniti, A. 2004: Storia delle scienze sperimentali.- Due letter di Odoardo Beccari a Guiseppe de Notaris: le epatiche di Borneo e le vicende di due grandi Italiani. *Rendiconti Fisiche e Accademia Lincei,* 9th ser. **15**: 159–168.

Hampe, E. & Geheeb, A. 1881: Musci frondosi in Tasmania et Nova-Seelandia a Dr. O. Beccari, anno 1878, lecti. *Revue Bryologique* **8**(2): 25–28.

Hooker, J.D. 1891: *Amorphophallus titanum.* Native of Sumatra. *Curtis's Botanical Magazine* 3rd series, **47**(553) (1247): 7153–7155.

Isoviita, P. & Ochyra, R. 1990: (975) Proposal to conserve *Drepanocladus* (Musci, Amblystegiaceae). *Taxon* **39**(2): 348–351.

Jackson, B.D. 1922: Obituary notices. *Proceedings of the Linnean Society of London* **134**: 37–40.

Lydon, J. 2014: Picturing Macassan-Australian histories: Odoardo Beccari's 1873 photographs of the "Orang-Mereghi" and indigenous authenticity. *In* Carey, J. & Lydon, J. (eds): *Indigenous Networks: Mobility, Connections and Exchange.* Routledge, New York: 140–166.

Mattirolo, O. 1897: *Enumerato seminum in R Horto Botanico Florentiono anno MDCCCXCVII collectorum.*

Moore, H.E. Jr. 1981: Odoardo Beccari (1843–1920). *Principes* **25**: 29–35.

Mueller, F. von. 1875–1877: *Descriptive Notes on Papuan plants,* Parts 1–5. Melbourne, George Skinner.

Mueller, F. von. 1877: Letter: Ferdinand von Mueller to Odoardo Beccari, 1877, 31 December. University of Florence, Science Library: Botany, Archives, Beccari 12/32.

Mueller, F. von. 1878a: Letter: Ferdinand von Mueller to Odoardo Beccari, 1878, 1 June. University of Florence, Science Library: Botany, Archives, Beccari 12/32.

Mueller, F. von. 1878b: Letter: Ferdinand von Mueller to William Thiselton-Dyer, 1878, 12 May, RBG Kew. Kew correspondence, Australia, Mueller, 1871–81, ff. 211–14.

Mueller, F. von. 1879: Letter: Ferdinand von Mueller to Odoardo Beccari, 1879, 5 April. University of Florence, Science Library: Botany, Archives, Beccari 12/32.

Mueller, F. von. 1880: *Select Extra-tropical Plants Readily Eligible for Industrial Culture or Naturalisation, with Indications of their Native Countries and Some of their Uses.* Office of the Superintendent of Government Printing, Calcutta: 394 pp.

Mueller, F. von. 1887: Letter: Ferdinand von Mueller to Odoardo Beccari, 1887, 10 March. University of Florence, Science Library: Botany, Archives, Beccari 12/32.

Mueller, F. von. 1890: Letter: Ferdinand von Mueller to Odoardo Beccari, 1890, 13 March. University of Florence, Science Library: Botany, Archives, Beccari 12/32.

Müller, C. 1897: Symbolae ad bryologiam Australiae I. *Hedwigia* **36**: 331–365.

Nepi, C. 2009: L'Erbario delle Malesia di Odoardo Beccari. *In* Raffaeli, M. (ed): *Il Museo di Storia Naturale dell'Università degli Studi di Firenze. Vol. 2, Le Collezioni Botaniche* Firenze University Press, Firenze: 117–132.

Nizamuddin, M., West, J.A. & Menez, E.G. 1978: A list of marine algae from Libya. *Botanica Marina* **22**: 465–476.

Orlandi, L. 2009: A "Turkish salon" in the domestic collection of the Genoese gentleman and traveller Enrico A. D'Albertis (1846–1932). *In* Dávid, G. & Gerelyes, I. (eds): *Thirteenth International Congress of Turkish Art.* Hungarian National Museum, Budapest: 519–531.

Pichi-Sermolli, R.E.G. & van Steenis, C.G.G.J. 1983: Dedicated to the memory of Odoardo Beccari. *Flora Malesiana,* 1st ser. **9**: 7–44.

Pollacci, G. 1935: Odoardo Beccari. *Atti dell'Istituto Botanico dell'Università di Pavia,* 4th ser. **6**: 1–13.

Ramsay, H.P. 2006: History of research on Australian mosses. *Flora of Australia* **51**: 1–19. Australian Biological Resources Study & CSIRO Publishing, Melbourne.

Ruffo, S. 1949: Studi sui crostacei anfipodi XVII, gli anfipodi del Museo Civico di Storia Naturale di Genova, anfipodi di Sumatra, Celebes, Nuova Guinea, Australia e Tasmania. *Annali del Museo Civico di Storia Naturale Giacomo Doria* **63**: 205–217.

Sayre, G. 1977: Authors names of bryophytes and the present location of their herbaria. *The Bryologist* **80**: 502–521.

Surdich, F. 1985: D'Albertis, Enrico Alberto. *Dizionario Biografico degli Italiani,* Vol. 31, www.treccani.it/enciclopedia (accessed October 2015).

Taylor, R.J. & McQuillan, P.B. 1994: Fauna of Mount Wellington. *The Tasmanian Naturalist* **116**: 2–19.

Van Steenis, C.G.G.J. 1952: Thesaurus Beccarianus. *Webbia* **8**: 427–436.

Van Steenis-Kruseman, M.J. 1950: Malaysian plant collectors and collections. *Flora Malesiana* **1**(1): vii–clii, 3–639.

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Appendix 1

AN ANNOTATED ITINERARY OF ODOARDO BECCARI AND ENRICO D'ALBERTIS IN AUSTRALIA/NEW ZEALAND, 1878

The details of the itinerary were derived from three primary sources: A diary kept by Beccari (1878a); a scrap book of receipts, dockets, business-cards and newspaper clippings kept by D'Albertis (1878) and D'Albertis' travel notes as presented by Fornaroli (1935) which dealt with the entire 1877–1878 period. Additional details were sourced from newspapers of the time, mostly in items related to shipping, editorials and social notes.

Dates	Locations and notes
1877	
24 Oct	Odoardo Beccari and Enrico D'Albertis depart Genoa, Italy, on the *M.S. Australia.*
1–3 Nov	Suez Canal, Port Said.
9 Nov	Aden.
16 Nov–12 Dec	Overland across India from Bombay [Mumbai] to Calcutta [Kolkata].
1878	
3 Dec – 7 Jan	Departed Calcutta on the *S.S. Mecca* to Burma [Myanmar], Penang, Malacca, Singapore and Sarawak.
7–10 Jan	Singapore.
11 Jan	Departed Singapore on the *S.S. Brisbane.*
19 Jan	Thursday Island.
20–21 Jan	Somerset.
23 Jan	Cooktown.
24 Jan	Townsville, Bowen. (*The Queenslander.* "Correspondent. Via Torres Straits". 26 January 1878, p. 21)
25 Jan	Percy Islands. D'Albertis (1878) reported in a letter to Giacomo Doria: "*We passed Bowen, then Percy Island in the Northumberland group where we made some collections, and finally to Keppel Bay*". The collections consisted of botanical and zoological specimens. The plant specimens were later deposited in Ferdinand von Mueller's Phytologic Museum of Melbourne, now the National Herbarium of Victoria, and the ant specimens were returned to the Museo Civico di Storia Naturale in Genoa.
26 Jan	Keppel Bay, Curtis Island.
27 Jan	Moreton Bay, Brisbane: visited the Botanic Garden and the observatory. (*The Brisbane Courier.* 'Shipping'. 28 January 1878, p. 2)
28 Jan	Departed Brisbane.
30 Jan– 2 Feb	Sydney [Royal Hotel]; granted honorary membership of the Australian Club (*The Australian Town and Country Journal.* 'Shipping'. 2 February1878, p. 36)
2 Feb	Departed Sydney by train to Bowning.
3 Feb	Departed Bowning by coach to Jugiong, Gundagai to Albury and then by train to Melbourne; at least two ant specimens were collected during the "overland" travel between Sydney and Melbourne.
4–11 Feb	Melbourne [Union Club Hotel, Collins Street West]. (*The Argus.* 'Editorial'. 6 February 1878, p. 5).
6 Feb	Melbourne; visited the Botanic Gardens with Ferdinand von Mueller, the Melbourne Observatory and met Robert Lewis John Ellery, Government Astronomer and President of the Royal Society of Victoria.
7 Feb	Visited Ballarat to examine the gold mines.
7 Feb	Melbourne; met with Sir Redmond Barry, Victorian Colonial Judge and Chancellor of the University of Melbourne, visited the Library, Museum, Hospital, Melbourne Club, Parliament House, Government Offices, Athenaeum Club and Zoological Gardens where they saw echidnas, the now extinct thylacine (Tasmanian tiger), dingoes and kangaroos.
8 Feb	Melbourne; visited the University and Museum, met Sir Frederick McCoy, Director of the Victorian Museum and Professor of Natural Sciences at Melbourne University.
9 Feb	Melbourne; lunched with John Pigdon, Mayor of Melbourne, met with the photographer John William Lindt who took a *carte-de-visite* of both Beccari and D'Albertis (see pls 1, 2) and in the evening dined at Government House with Governor George Ferguson Bowen and Lady Bowen, Contessa Diamantina di Roma.
12 Feb	Departed Melbourne for Tasmania on the *S.S. Derwent.*
13 Feb	Tamar Heads, Corra Linn, Deloraine, Launceston [Criterion Hotel]. (*The Mercury.* 'By electric telegraph. Tamar Heads'. 14 February 1878, p. 2); Collected plant and ant specimens.
16 Feb	Departed Launceston by train to Hobart.
16–23 Feb	Hobart [Ship Hotel].
19 Feb	Mount Wellington; collected bryophytes, vascular plants, crustaceans and earthworms at Huon Road and Mount Wellington (Taylor & McQuillan 1994). On Mount Wellington, D'Albertis measured a giant *Eucalyptus* to 76 m tall with a circumference of 13.2 m.

Appendix 1 cont.

20 Feb	Hobart, New Norfolk; visited the museum and gardens, and the salmon hatchery. At this time, "eight prepared skins of New Guinea birds" collected by Beccari were received by the Royal Society of Tasmania (Anon. 1879). It is possible that Beccari delivered them personally, however no record survives of the mode of delivery (Kathryn Medlock pers. comm.).
23 Feb	Departed Hobart for New Zealand on the *S.S. Tararua*.
26–27 Feb	Bluff Harbour, Invercargill. (*The Southland Times*. 'Bluff Harbour'. 28 February 1878, p. 2). A bryophyte specimen was collected at Bluff.
28 Feb	By railway to Clinton.
29 Feb– 2 Mar	By coach to Balclutha, Dunedin.
2 Mar	Dunedin, Moeraki, Blueskin Bay via Port Chalmers. D'Albertis recorded that they collected seeds of *Cordyline australis* [as *Dracoena*], "Ombrellaria" [possibly *Schefflera digitata*] and *Rhopalostylis sapida* [Nikau palm].
3 Mar	By train to Mount Omaru, via Timaru to Christchurch.
4 Mar	Christchurch; Canterbury Museum, met with Julius von Haast.
5 Mar	Departed Lyttelton on the *S.S. Taupo*. (*The Star*. 'Sailed'. 6 March 1878, p. 2).
6 Mar	Wellington (*The Evening Post*. 'Shipping'. 6 March 1878, p. 2).
7 Mar	Departed Wellington by train for Napier and reboarded the *S.S. Taupo* at Hawke's Bay. They collected an ant specimen from Napier.
8 Mar	Hawke's Bay [Napier] (*The Hawke's Bay Herald*. "Arrivals". 9 March 1878, p. 2).
9 Mar	Poverty Bay [Gisborne], Tauranga.
10–12 Mar	Auckland [Northern Club] (*The New Zealand Herald*. "Shipping". 11 March 1878, p. 2).
11 Mar	Auckland; visited the Auckland Museum and Institute and met Justice Thomas Gillies and geologist James Hector (*The New Zealand Herald*. [Editorial]. 12 March, 1878, p. 2). Later the same day they were taken to the Waitakerei Ranges and Titirangi by the botanist Thomas Cheeseman. (*The New Zealand Herald*. [Editorial]. 13 March, 1878, p. 2). Specimens were collected by Beccari at Titirangi, including bryophytes, ants, an earthworm and a specimen of the nikau palm *Rhopalostylis sapida* (Cuccuini & Nepi 2006).
12 Mar	Departed Auckland for Australia on the *R.M.S. Australia* (*The Auckland Star*. "Departure of the Australia". 13 March 1878, p. 2).
17–23 Mar	Arrived in Sydney [Royal Hotel] (*The Evening News*. "Shipping". 18 March 1878, p. 2).
18–19 Mar	Travelled by train to the Blue Mountains; D'Albertis noted that they collected specimens of plants, "blues" [butterflies?] and ants. However, only specimens of the latter have been located.
23 Mar	Departed Sydney on the *R.M.S. Bowen*.
25 Mar	Brisbane (*The Morning Bulletin*. "Shipping Movements". 1 April 1878, p. 2).
26 Mar	Overnight train to Toowoomba.
27 Mar	Brisbane [Metropolitan Hotel].
28 Mar	Beccari visited the Brisbane Botanic Gardens and collected specimens of the palms *Archontophoenix alexandrae* and *Syagrus romanzoffiana* (Cuccuini & Nepi 2006). Beccari made a brief diary note about the palm collection: "*Caryota alberti [I] saw a specimen with trunk 30 feet high [in the] Botanical Gardens of Brisbane. Surely it doesn't seem to look like C. rumphii. Saguerus of C. York, is different to S. saccharifer because it is stoloniferous. In Brisbane [there are] various species of Cocos, Caryota, Arenga, Licuala. They survive very well outdoors*" (Beccari 1878a). Beccari was to later clarify his identification of the *Caryota* species that he saw in Brisbane Botanic Gardens, noting that it: "*seems very likely that the Caryota alberti F. von Mueller from Cape York is identical to the Caryota from the Fly River. Indeed I saw a fine specimen of the species from Cape York living in the Brisbane Botanic Gardens, and based on the size and shape of the trunk it was similar to Caryota rumphiana*" (Beccari 1878b).
28 Mar	Departed Brisbane on the *R.M.S. Bowen*.
29 Mar	Keppel Bay (*The Brisbane Courier*. 'Shipping'.1 April 1878, p. 2).
30 Mar	Bowen.
31 Mar	Townsville.
1 Apr	Cooktown.
5 Apr	Thursday Island (*The Brisbane Courier*. "Shipping". 3 April 1878, p. 2).
15 Apr	Singapore (*The Straits Times*. "Overland Journal". 18 April 1878, p. 1).
14 Oct	D'Albertis arrived at Genoa.
28 Dec	Beccari arrived at Florence.

Appendix 2

VASCULAR PLANTS, BRYOPHYTES, CRUSTACEANS, ANTS AND EARTHWORMS COLLECTED BY ODOARDO BECCARI AND ENRICO D'ALBERTIS IN AUSTRALIA AND NEW ZEALAND, 1878

New species based on a Beccari/D'Albertis specimen are preceded by an *. The original name appears first, and the current name follows in brackets. Collection date is known or determined from the travel itinerary. Location of specimens is given where known. Taxonomy and nomenclature of Australian vascular plants follows the *Australian Plant Name Index* and for New Zealand vascular plants the *Flora of New Zealand*; Bryophyte taxonomy follows *AusMoss*; Ant taxonomy follows the *Atlas of Living Australia* and *AntWeb*; and Earthworms follow the *ITIS Report*.

Herbarium and museum acronyms. **B**: Botanischer Garten und Botanisches Museum Berlin-Dahlem, Germany; **BM**: Natural History Museum, London; **FI**: Museo di Storia Naturale dell'Università di Firenze, Italy; **H-BR**: University of Helsinki, Finland; **L**: Nationaal Herbarium Nederland, The Netherlands; **MEL**: National Herbarium of Victoria, Royal Botanic Gardens Melbourne, Australia; **MSNG**: Museo Civico di Storia Naturale di Genova, Italy; **TENN**: University of Tennessee, USA; **NSW**: National Herbarium of New South Wales, Royal Botanic Gardens Sydney, Australia; **NY**: The New York Botanical Garden, The Bronx, USA.

Original name, current name and specimen; location of specimen	**Citation or publication reference**
VASCULAR PLANTS	
**Acaena sanguisorbae* var. *brevifoliolata* Bitter; Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari s.n.*; FI	*Biblioth. Bot.* 17(74): 263 (1911).
**Acaena sanguisorbae* var. *subincisa* Bitter; Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari s.n.*; FI	*Biblioth. Bot.* 17(74): 263 (1911).
Allocasuarina littoralis (Salisb.) L.A.S.Johnson, Australia, Qld. Percy Islands, 1878, *Beccari s.n.*; MEL 0545833.	n/a
Archontophoenix alexandrae (F.Muell.) H.Wendl. & Drude Australia, Brisbane Botanic Garden, 28 Mar. 1878, *O. Beccari s.n.;* FI.	*Quad. Bot. Amb. Appl.* 17: 149 (2006).
Coronidium cymosum Paul G.Wilson, Australia, Qld. Percy Islands, 1878, *Beccari s.n.*; MEL 2115498.	n/a
Helichrysum elatum A.Cunn. ex DC.[*Coronidium elatum* (A.Cunn. ex DC.) Paul G. Wilson], Australia, Qld. Percy Islands, 1878, *Beccari s.n.*; MEL 2160996.	n/a
Grewia retusifolia Kurz, Australia, Qld. Percy Islands, 1878, *Beccari s.n.*; MEL 1599215.	n/a
Leucopogon leptospermoides R.Br., Australia, Qld. Percy Islands, 1878, *Beccari s.n.*; MEL 0088992.	n/a
Pityrodia salviifolia R.Br., Australia, Qld. Percy Islands, 26 Jan, 1878, *Beccari s.n.*; FI.	*J. Adelaide Bot. Gard.* 2: 10 (1979).
Portulaca sp., Australia, Qld. Percy Islands, 1878, *Beccari s.n.*; MEL 0025735.	n/a
Rhopalostylis sapida (Sol. ex G.Forst.) H.Wendl. & Drude; New Zealand, North Island, Titirangi Range near Auckland, 12 Mar. 1878, *Beccari s.n.*; FI.	*Quad. Bot. Amb. Appl.* 17: 150 (2006).
Senecio quadridentatus Labill.; Australia, Tasmania, 'Corra Leen' [Corra Linn], 13 Feb. 1878, *Beccari s.n.*; FI.	*Ann. Missouri Bot. Gard.* 43: 58. (1956).
Cocos romanzoffiana Cham. [*Syagrus romanzoffiana* (Cham.) Glassman]: Australia, Brisbane Botanic Garden, *Beccari s.n.*; FI.	*Quad. Bot. Amb. Appl.* 17: 66 (2006).
BRYOPHYTES	
**Bryum beccarii* Müll.Hal. [*Pohlia nutans* (Hedw.) Lindb.]; Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari s.n.* [Named for Odoardo Beccari, collector of the type specimen].	*Hedwigia* 37: 87 (1898).
**Dicranum brunneum* Müll.Hal., Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari s.n.*	*Hedwigia* 36: 352 (1897).
**Dicranum campyperoideum* Müll.Hal., New Zealand, Titirangi, 11 Mar.1878, *Beccari s.n.*; [Herb. Geheeb] BM.	*Hedwigia* 36: (1897).
**Dicranum kroneanum* Müll.Hal., Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 13*; holotype B, destroyed; lectotype: L. [Named for Hermann Krone (1827–1916), German photographer and bryophyte collector who visited Australia and New Zealand in 1874–75].	*Rev. Bryol.* 8: 26 (1881).
**Dissodon longicollis* Müll.Hal. [*Tayloria octoblepharis* (Hook.) Mitt.], New Zealand, North Island, *Beccari s.n.*; B? destroyed?	*Gen. musc. Frond.* 124 (1901).

Appendix 2 cont.

**Fissidens tortuosus* Geh. & Hampe [*Fissidens rigidulus* Hook.f. & Wilson var. *rigidulus*]; Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 25.*	*Rev. Bryol.* 8: 27 (1881).
**Leptotheca beccarii* Müll.Hal. [*Leptotheca gaudichaudii* Schwägr. *var. gaudichaudii*], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 22*; lectotype: FI; isolectotype: NY00913954. [Named for Odoardo Beccari, collector of the type specimen]	*Gen. musc. Frond.* 148 (1901).
**Mniadelphus beccarii* Müll.Hal. [*Distichophyllum rotundifolium* (Hook.f. & Wilson) Müll.Hal. & Broth.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari s.n.* [Named for Odoardo Beccari, collector of the type specimen]	*Rev. Bryol.* 8: 26 (1881).
**Polytrichum beccarii* Müll.Hal. [*Polytrichum juniperinum* Hedw.]; Australia, Tasmania, Mt Wellington, 19 Feb, 1878, *Beccari s.n.*: isotype: H-Br. [Named for Odoardo Beccari, collector of the type specimen]	*Hedwigia* 36: 345 (1897).
**Pterygophyllum levieri* Geh. [*Distichophyllum microcarpum* (Hedw.) Mitt.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 41.* [Named for Emilio Levier (1839–1911), Swiss-born physician and bryologist, resident of Florence]	*Rev. Bryol.* 8: 27 (1881).
**Raphidostegium calliferum* Geh. & Hampe [*Rhaphidorrhynchium amoenum* (Hedw.) M.Fleisch. var. *amoenum*]; Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 31.*	*Rev. Bryol.* 8: 27 (1881).
Andreaea acuminata Mitt., 19 Feb. 1878, Australia, Tasmania, Mt Wellington.	*Rev. Bryol.* 8: 25 (1881).
Bartramia mossmanniana Müll.Hal., Australia, Tasmania, Huon Rd., Mt Wellington, 19 Feb. 1878, *Beccari 9.*	*Rev. Bryol.* 8: 26 (1881).
Blindia robusta Hampe, Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 12*; TENN-B-0005029.	*Rev. Bryol.* 8: 25 (1881).
Breutelia comosa Mitt. [*Breutelia pendula* (Sm.) Mitt.]; Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 26*; TENN-B-0007650.	*Rev. Bryol.* 8: 26 (1881).
Campylopus capillatus Hook.f. & Wilson [*Campylopus pyriformis* (Schultz) Brid.], New Zealand, Titirangi near Auckland, 11 Mar. 1878, *Beccari 34.*	*Rev. Bryol.* 8: 26 (1881).
Campylopus insititius Hook.f. [*Campylopus clavatus* Wilson], Australia, Tasmania, Mt. Wellington, 19 Feb. 1878, *Beccari 15.*	*Rev. Bryol.* 8: 26 (1881).
Campylopus introflexus (Hedw.) Brid., New Zealand, Titirangi near Auckland, 11 Mar. 1878, *Beccari 39*].	*Rev. Bryol.* 8: 26 (1881).
Campylopus torquatus Mitt. [*Campylopus pyriformis* (Schultz) Brid.], Australia, Tasmania, Huon Road, Mt Wellington, 19 Feb. 1878, *Beccari 14.*	*Rev. Bryol.* 8: 26 (1881).
Ceratodon crassinervis Lorentz [*Ceratodon purpureus* (Hedw) Brid.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 2.*	*Rev. Bryol.* 8: 25 (1881).
Coelidium chlamydophyllum (Hook.f. & Wilson) A.Jaeger [*Acrocladium chlamydophyllum* (Hook.f. & Wilson) Müll.Hal. & Broth.], Australia, Tasmania, 19 Feb. 1878, *Beccari 29.*	*Rev. Bryol.* 8: 27 (1881).
Conostomum australe Sw. [*Conostomum pentastichum* (Brid.) Lindb.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 8.*	*Rev. Bryol.* 8: 26 (1881).
Cyathophorum bulbosum Müll.Hal., Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 33.*	*Rev. Bryol.* 8: 28 (1881).
Cyrtopus setosus (Hedw.) Hook.f., New Zealand, Titirangi near Auckland, 11 Mar. 1878, *Beccari 31.*	*Rev. Bryol.* 8: 25 (1881).
Dissodon cuspidatus Müll.Hal. [*Tayloria octoblepharum* (Hook.) Mitt.], New Zealand, Bluff, 26 Feb. [as Mar.] 1878, *Beccari 38.*	*Rev. Bryol.* 8: 25 (1881).
Distichium capillaceum (Hedw.) Bruch & W.P. Schimper, Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 3.*	*Rev. Bryol.* 8: 25 (1881).
Gottschea lehmanniana (Lehm. & Lindenb.) Nees] [*Schistochila lehmanniana* (Lehm. & Lindenb.) Carrington & Pearson]; Australia, Tasmania, Mt Wellington, *Beccari s.n.*	*Fragm.* (Suppl.) 11: 61 (1880).
Hypnum chrysogaster Müll.Hal., Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 28*; NSW 760254.	*Rev. Bryol.* 8: 27 (1881).
Hypnum crinitum Hook. & Wilson [*Wijkia extenuata* (Brid.) H.A.Crum], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 30.*	*Rev. Bryol.* 8: 27 (1881).
Leptostomum flexipile Müll.Hal. [*Leptostomum inclinans* R.Br.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 5.*	*Rev. Bryol.* 8: 26 (1881).
Leptotheca gaudichaudi Schwägr., Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 22 & 23.*	*Rev. Bryol.* 8: 26 (1881).

Appendix 2 cont.

Leptotrichum oldfieldii Mitt. [*Ditrichum difficile* (Duby) M.Fleisch], Australia, Tasmania, Huon Road, Mt Wellington, 19 Feb. 1878, *Beccari 1.*	*Rev. Bryol.* 8: 25 (1881).
Mniadelphus pulchellus Hampe [*Distichophyllum pulchellum* (Hampe) Mitt.], Australia, Tasmania, Mt Wellington, Australia, 19 Feb. 1878, *Beccari 24.*	*Rev. Bryol.* 8: 26 (1881).
Mniodendron comatum (Müll.Hal.) Lindb., New Zealand, Titirangi near Auckland, 11 Mar. 1878, *Beccari 36.*	*Rev. Bryol.* 8: 27 (1881).
Philonotis fertilis Mitt. [*Philonotis tenuis* (Taylor) Reichardt], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 7.*	*Rev. Bryol.* 8: 26 (1881).
Pogonatum australasicum (Müll.Hal. & Hampe) A.Jaeger [*Pogonatum neesii* (Müll.Hal.) Dozy], Australia, Tasmania, Huon Road, Mt Wellington, 19 Feb. 1878, *Beccari 16.*	*Rev. Bryol.* 8: 26 (1881).
Polytrichadelphus arnoldii (Hampe) A.Jaeger [*Polytrichadelphus magellanicus* (Hedw.) Mitt.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 17.*	*Rev. Bryol.* 8: 26 (1881).
Polytrichum sullivani Hampe [*Polytrichum juniperinum* Hedw.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 16.*	*Rev. Bryol.* 8: 26 (1881).
Psilopilum australe (Hook.f. & Wilson) Mitt. [*Notoligotrichum australe* (Hook.f. & Wilson) G.L.Sm.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 18.*	*Rev. Bryol.* 8: 26 (1881).
Ptychomnium aciculare (Brid.) Mitt., Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 27*; New Zealand, Titirangi near Auckland, 11 Mar. 1878, *Beccari 35.*	*Rev. Bryol.* 8: 27 (1881).
Rhizogonium novae-hollandiae (Brid.) Brid., Australia, Tasmania, undated, *Beccari 20 & 21.*	*Rev. Bryol.* 8: 26 (1881).
Rhizogonium paramattense (Müll.Hal.) Reichardt [*Pyrrobryum paramattense* (Müll.Hal.) Manuel], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 6.*	*Rev. Bryol.* 8: 26 (1881).
Sphagnum australe Mitt., Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 32.*	*Rev. Bryol.* 8: 25 (1881).
Trichostomum elongatum Hook.f. & Wilson [*Ditrichum cylindricarpum* (Müll.Hal.) F.Muell.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 10.*	*Rev. Bryol.* 8: 25 (1881).
Trichostomum laxifolium Hook.f. & Wilson [*Ditrichum difficile* (Duby) M.Fleisch], Australia, Tasmania, Mt Wellington, 19 Feb, 1878, *Beccari 1.*	*Rev. Bryol.* 8: 25 (1881).
Webera nutans Hedw. [*Pohlia nutans* (Hedw.) Lindb.], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari 4.*	*Rev. Bryol.* 8: 26 (1881).
CRUSTACEANS	
**Keratroides vulgaris* (Friend, 1979), Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari & E.D'Albertis s.n.*; MSNG.	*Pap. & Proc. Roy. Soc. Tasmania* 113: 85 (1979).
**Mysticotalitrus tasmaniae* (Ruffo, 1949) [*Talitrus tasmaniae* (Ruffo, 1949)], Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari & E.D'Albertis s.n.*; syntype: MSNG.	*Ann. Mus. Civico Storia Nat. Giacomo Doria* 63: 207 (1949).
Talitrus sylvaticus (Haswell, 1879), Australia, Tasmania, Mt Wellington, 19 Feb. 1878, *Beccari & E.D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Giacomo Doria* 63: 206 (1949).
ANTS	
**Camponotus dorycus confusus* (Emery, 1887), Australia, Percy Island, *Beccari & E.D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 215 (1887).
**Camponotus nigriceps pallidiceps* (Emery, 1887) [*Camponotus pallidiceps* (Emery, 1887)], Australia, Blue Mts, *Beccari & Enrico D'Albertis s.n.*; syntype: MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 211 (1887).
**Dolichoderus doriae* (Emery, 1887), Australia, Blue Mts, *Beccari & Enrico D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 252 (1887).
Amblyopone australis (Erichson, 1842), Australia, Tasmania, Launceston, *Beccari & E.D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(5). 25: 446 (1887).
Amblyopone cephalotes (Smith, 1876) [*Amblyopone australis* (Erichson, 1842)], New Zealand, Napier, *Beccari & E. D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(5), 25: 446 (1887).
Camponotus ephippium (Smith, 1858), Australia, New South Wales, Overland, *Beccari & Enrico D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 211 (1887).
Camponotus intrepidus (Kirby, 1818), Australia, Blue Mts, *Beccari & Enrico D'Albertis s.n.*; MSNG	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 210 (1887).

Appendix 2 cont.

Camponotus nigreceps dimidiatus (Roger, 1863) [*Camponotus consobrinus* (Erichson, 1842)], Australia, Blue Mts; Tasmania, Launceston, *Beccari & E.D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 211 (1887)
Ectatomma metallicum (Smith, 1858) [*Rhytidoponera metallica* (Smith, 1858)], Australia, Tasmania, Launceston, *Beccari & E.D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 25: 444 (1887).
Iridomyrmex itinerans (Lowne, 1865) [*Anonychomyrma itinerans* (Lowne, 1865)], Australia, Blue Mts, *Beccari & Enrico D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 249 (1887).
Iridomyrmex purpureus (Smith, 1858), Australia, Overland, *Beccari & Enrico D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 249 (1887).
Iridomyrmex rufoniger (Lowne, 1865), Australia, Percy Island, Overland, *Beccari & E.D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 251 (1887).
Leptomyrmex erythrocephalus (Fabricius, 1775), Australia, Blue Mts, *Beccari & Enrico D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 252 (1887).
Leptomyrmex erythrocephalus nigriventris (Guérin, 1831), Australia, Blue Mts, *Beccari & Enrico D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 252 (1887).
Monomorium antarcticum (Smith, 1858), New Zealand, Titirangi, *Beccari & E. D'Albertis s.n.* MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(5), 25: 458 (1887).
Myrmecia auriventris (Mayr, 1870), Australia, Percy Island, *Beccari & E.D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(5). 25: 444 (1887).
Myrmecia forficata (Fabricius, 1787), Australia, Tasmania, Launceston, Deloraine, *Beccari & E.D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(5), 25: 443(1887).
Myrmecia pilosula (Smith, 1858), Australia, Blue Mts, Tasmania, Launceston, *Beccari & Enrico D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(5), 25: 444 (1887).
Myrmecia pyriformis (Smith, 1858), Australia, Blue Mts, *Beccari & E. D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(5), 25: 443 (1887).
Polyrhachis femorata (Smith, 1858), Australia, Blue Mts, *Beccari & Enrico D'Albertis s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 2(4), 24: 225 (1887).
EARTHWORMS	
**Megascolides albertisii* (Cognetti de Martiis, 1910) [*Aporodrilus albertisii* (Cognetti de Martiis, 1910)], Australia, Tasmania, Mt Wellington, 19 Feb., 1878, *E.D'Albertis & Beccari s.n.*; MSNG [Named for Enrico D'Albertis, collector of the type specimen].	*Ann. Mus. Civico Storia Nat. Genova*, ser. 3(4), 44: 329 (1910).
**Megascolides neglectus* (Cognetti de Martiis, 1910), New Zealand, Titirangi near Auckland, 11 March 1878, *E. D'Albertis & Beccari s.n.*; MSNG.	*Ann. Mus. Civico Storia Nat. Genova*, ser. 3(4), 44: 327 (1910).

A NEW SPECIES OF ONISCIGASTRID MAYFLY FROM TASMANIA, *TASMANOPHLEBIA LOTIS*, WITH COMMENTS ON THE AUSTRALIAN ONISCIGASTRID SPECIES

by Ronald E. Thresher

(with three text-figures, five plates and an appendix)

Thresher, R.E. 2016 (15:xii): A new species of Oniscigastrid mayfly from Tasmania, *Tasmanophlebia lotis*, with comments on the Australian Oniscigastrid species. *Papers and Proceedings of the Royal Society of Tasmania* 150(2): 43–57. ISSN 0080-4703. 50 Bramble Street, Ridgeway, Tasmania 7054, Australia. Email: ronaldethresher@gmail.com

Imagoes, sub-imagoes and nymphs of a new species of Tasmanian mayfly (*Tasmanophlebia lotis* sp.nov.) are described based on morphological, ecological and genetic differences between it, the only other known Tasmanian species in the genus (*T. lacustris*) and congeneric species on the Australian mainland. *Tasmanophlebia lotis* is widely distributed in rivers at low elevations across the island, in contrast to *T. lacustris*, which is found in high-altitude lentic habitats. The separation of mainland Australian and Tasmanian species of *Tasmanophlebia* is consistent with similar observations based on genetic analysis of other Australian mayflies, and suggests differentiation well prior to the flooding of Bass Strait during Holocene deglaciation.

Key Words: CO1 mitochondrial DNA, genetics, imago, mating behaviour, nymph, sub-imago, *Tasmanophlebia lotis*.

INTRODUCTION

The mayfly family Oniscigastridae is represented in Australia by three described species, all in the genus *Tasmanophlebia* (Hubbard & Campbell 1996). All are large and conspicuous, and often of importance to recreational fishers (e.g., Scholes 1961). In Tasmania, only one species has been described, *Tasmanophlebia lacustris* Tillyard, 1921 (see also Tillyard 1935), from adult imagoes and sub-imagoes collected from lakes on the Central Plateau (hence the common name, highland spinner) (Tillyard 1921). Subsequently, Riek (1955, p. 269), in his review of the family as it was then considered (Siphlonuridae, subfamily Siphlonurinae), noted first, that the genus was "well represented in the lakes and streams at high altitudes...in Tasmania" and second, that there was a degree of variability in a few features in *T. lacustris*, including differences among individuals in the position that the MP vein forks in the hind wing and in the shape of the claspers. More recently, Scholes (1961, p. 66), in a popular book on fly-fishing in Tasmania, reported collecting an "as yet unrecorded" species of Siphlonuridae from the South Esk River (northeast Tasmania), describing it as similar to *T. lacustris*, but smaller and in the sub-imago having a "curved bar of clear space...across both sets of wings". He further describes the general colouring of both the sub-imago ("pale grey") and imago ("dark olive brown above, ...underside paler, ...wings are glassy-clear").

In 1988, I collected sub-imagoes of a *Tasmanophlebia* from the Ringarooma River (also in northeast Tasmania) and the Styx River (southern Tasmania). Subsequent collections indicate, first, that the insect is broadly distributed in fast-flowing lowland rivers throughout Tasmania (see below); second, that they match the description given by Scholes (1961) for specimens from the South Esk River; and third, that they are very similar to a described mainland species, *T. nigrescens*. In that regard, the Museum of Victoria (MoV) holds a number of specimens collected in northern Tasmanian streams that are attributed to *T. nigrescens*, while Suter (1980) reported another mainland species, *T. lacus-coerulei*, as present in northern Tasmanian rivers.

In this paper, I describe the insect as a new species, *Tasmanophlebia lotis* sp. nov., on the basis of conspicuous morphological differences between it and the only other previously reported Tasmanian species, *T. lacustris*, and a CO1 genetic analysis (see Hebert *et al.* 2003). Information is also provided on the general biology of the two *Tasmanophlebia* species in Tasmania.

MATERIALS AND METHODS

Procedures for measuring and describing specimens broadly follow Suter (1986). Mayfly systematics follows Hubbard (1990). Protocols for genetic analysis broadly follow Folmer *et al.* (1994). DNA samples were extracted using phenol/chloroform with precipitation from the aqueous solution using ethanol and a CTAB (hexadecyltrimethylammonium bromide) protocol modified according to Grewe *et al.* (1993). The cytochrome c oxidase subunit 1 (CO1) region was amplified from all isolates by polymerase chain reaction (PCR) using the primers HCO2198 (5′-TAAACTTCAGGGTGACCAAAAAATCA-3′) and LCOI490 (5′-GGTCAACAAATCATAAA GATATTGG-3′) (Folmer *et al.* 1994). The DNA was denatured at 94°C for 15 seconds, primers annealed at 50°C for 15 seconds and chains extended at 72°C for 2 minutes, for 35 cycles. The primer set amplified a 652 bp segment of the cytochrome oxidase 1 mitochondrial gene. The amplified product was confirmed on 1.2% agarose gels stained with ethidium bromide. Amplified products were purified with QIAquick spin PCR purification kits

PLATE 1 — Male and female imagoes and sub-imago of the two Tasmanian species of *Tasmanophlebia*. All *T. lotis* (a, male imago; b, female imago; c, sub-imago) from Mountain River (SE Tasmania); (d) *T. lacustris* male imago from Little Pine Lagoon, and (e) female imago and (f) sub-imago from Ada Lagoon, both locations on the Tasmanian Central Plateau. Note that the forewings on the female imago of *T. lotis* (b) are damaged.

(QIAGEN INC., Chatsworth). Each PCR product was sequenced in both forward and reverse directions using Big Dye Terminator chemistry and run on an automated sequencer (ABI 3100 DNA capillary sequencer) according to the manufacturer's instructions. After primer sequences were removed, nucleotide sequence data were aligned and consensus sequences obtained using Seqman (DNA Star). Mega 7 (Kumar *et al.* 2016) was used to construct a molecular phylogeny using the Maximum Likelihood Method (Tamura & Nei 1993). Relative time since separation for major branch points was determined using the RelTime method, following Tamura *et al.* (2012), and the probability of branching estimated by bootstrapping (500 replicates).

For the genetic analysis, DNA was extracted from one or more legs of sub-imago and nymphal specimens preserved

for less than one year in ethanol (90%). Samples of *T. lotis* were from three sites (Ringarooma River (one sub-imago), South Esk River (two sub-imagoes) and Mountain River (one sub-imago)); and those of *T. lacustris* were from two sites (Little Pine Lagoon (two sub-imagoes and a nymph) and an un-named lagoon near Pillans Lake (one nymph)). The mainland *Tasmanophlebia* sequenced were from the Kiewa River in Victoria (one sub-imago)) and the Swampy Plains River in NSW (one sub-imago and one nymph). Both specimens of *T. lacus-coerulei* sequenced were collected as sub-imagoes at the type locality, Blue Lake, Snowy Mountains, NSW. As an out-group for the genetic analysis, I also sequenced DNA extracted from a *Coloburiscoides giganteus* nymph (Coloburiscidae) collected in the Thredbo River, NSW.

Additional CO1 data for a pair of Tasmanian nymphs (from Benson Creek and the Weld River) and five mainland specimens (nymphs from the Rocky Valley River and Big Pats Creek, Victoria, and Thredbo River, NSW; two specimens, unspecified life history stage, from Fyans Creek, Victoria) were graciously provided by P. Suter. Analytic details are provided in Webb & Suter (2011).

Photographs in the field were taken with a Nikon Coolpix and Canon 750D. Laboratory images were captured using a Leica MZ16FA microscope and Leica Application Suite 4.0 through a DFC310FX camera.

TAXONOMY

Tasmanophlebia lotis sp. nov.

Types: Tasmania: holotype, male imago, Mountain River, Tas. (42° 56'44" S; 147° 07'58" E), 9 March 2002, R. Thresher; paratypes: male and female imagoes, South Esk River below Mathinna, Tas. 12 March 2009; sub-imago, South Esk River below Mathinna, Tas., 28 December 2001; nymph, Hellyer River, Tas., 30 December 2015; nymph, Huon River, Tas., 29 December 2003. Specimens lodged at the Australian National Insect Collection (ANIC), Canberra, ACT

Etymology: *lotis*, based on lotic (Merriam-Webster dictionary definition: "living in actively moving water" (www.merriam-webster.com/dictionary), reflecting the preferred habit of the species (fast-flowing, cobble and gravel rivers). Contrasted with the Tasmanian still-water species *T. lacustris*, for which the species name is derived from lacustrine, defined as "living in or growing in lakes".

Description: Male imago (pl. 1): Overall black with white highlights on thorax. Abdomen dark grey dorsally, white ventrally with rufous spots. Wings clear with black veins and pigmented pterostigma. Forewing 9.48–10.5 mm long; hind wing 4.54–4.91 mm. Forelegs black, shading to grey distally; 10.4 mm long; ratio of segment lengths 2.52; 1.77; 1.97; 1.39; 1.24; 1.20; 0.57. Other legs white with black pigment at joints. Tarsi dissimilar on all legs. Clasper three-segmented. Penis elongate and forked, with large openings dorsally at tips (pl. 2). Without external spines. Body length 11–12 mm; cerci 16 mm. Appendix dorsalis reduced. Female imago (pl. 1): Overall reddish brown with black thorax. Wings clear. Body length 11–11.2 mm. Sub-imago (both sexes) (pl. 1): Overall grey, darker dorsally, with pale grey legs. Wings pale grey with darker grey veins, except for a conspicuous band of lighter grey on the forewing immediately behind area of overlap with hind wing. Hind wing also appears to have a pale section ventrally, but this is due principally to the contrast between where it does and does not overlap with the forewing. In life, the sub-imago appears to have a conspicuous oblique white band across the forewing. Body length 9.5–12.5 mm.

Nymphs: Male and female similar, other than genitalia and eye size (smaller in females). Size range of mature individuals 8.9–12.9 mm body length, 12.9–17.9 mm total length. Nymph elongate, cylindrical when small but becoming increasingly dorsoventrally flattened with age/size. Overall colour mottled, grey to reddish brown, with conspicuous narrow bands on legs and cerci (pl. 3). Prominent paired pigment spots along ventral mid-line of abdomen, lacking in *T. lacustris*. Head small and round. Eyes black in female, black below and reddish brown above in males. Prominent white spot rimmed with black, forming an ocellus, between antennae. Antennae 9-segmented. Mouthparts generally similar to those described by Tillyard (1933) for *T. lacus-coerulei* and *T. nigrescens* and for a South Australian *Tasmanophlebia* spp. (as *T. lacus-coerulei*) by Suter (1986). However, the grinding plate on the right mandible of *T. lotis* appears to be narrower than that of other species, and the grinding plate of the left mandible is conspicuously falcate as compared to the straight-edged plates in *T. lacustris* and in the *Tasmanophlebia* sp. I collected in lowland rivers from Victoria and NSW (*Tasmanophlebia* sp. AV2, see below) and the slightly falcate plate in *T. lacus-coerulei* (pl. 4). Thorax widening posteriorly. Wing sheaths reaching to approximately 1/4 length of the gills on large specimens. Gills on abdominal segments 1–4. First gills pigmented and broadly triangular. Gills 2–4 translucent, fringed with setae and bi-lobed. Abdomen in mature nymphs dorso-ventrally flattened with prominent lateral scutes. Prominent dorsal crest on abdominal segments 2-8.

Diagnosis and comparison with other species of *Tasmanophlebia*: As adults, *T. lotis* is smaller (length excluding cerci usually less than 12 mm) than either the other Tasmanian species (*T. lacustris*, 12–15 mm) or *T. lacus-coerulei* (>15 mm), but similar in size to *Tasamanophlebia* spp. in Victoria, NSW, and, based on Suter (1986), South Australia. Although Tillyard (1933) and subsequently Riek (1955) distinguished *T. lacus-coerulei* from other *Tasmanophlebia* species on the basis of large size, in general, and large size of the forewing in particular, lengths of the fore and hindwings are the same linear function of body length in all species (fig. 1), but because the slopes of the relationships are less than 1.0 (BL vs FWL, slope = 0.68, 95% CI 0.52–0.84; BL vs HWL, slope = 0.47, CI 0.37–0.57), the wings of the small species and individuals (including *T. lotis*) are proportionately larger than those of larger species and individuals. Similarly, maximum width of the wings scales

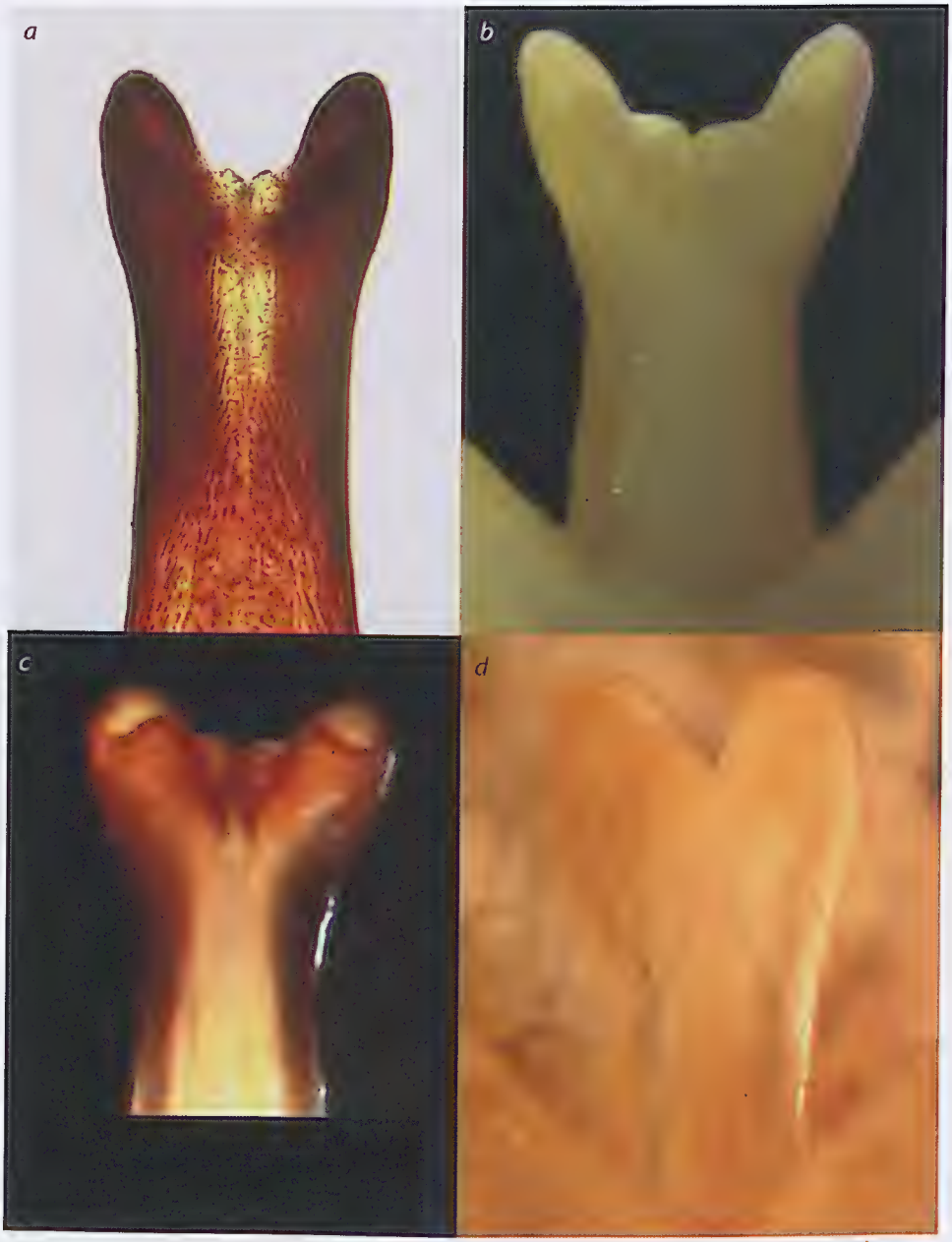

PLATE 2 — Genitalia (ventral views) of male imagoes of three described species of *Tasmanophlebia*. (a) *T. lotis*, North West Bay River, Tasmania); (b) *T.* sp. AV2, Little Snowy River, Victoria; (c) *T. lacustris*, Lake Augusta, Tasmania; (d) *T. lacus-caerulei*, Blue Lake, NSW.

linearly with their length in the same way across species, but because of slopes that are again less than one (FW, slope = 0.33, CI 0.26–0.39; HW, slope = 0.51, CI 0.39–0.64), small species/individuals have fore and hindwings that are proportionately wider than those of larger species/individuals. No combination of wing ratios separates any of the four described taxa (as well as specimens from South Australia described by Suter, 1986) (fig. 1). Wing venation is also similar in the three described species and *T. lotis*, though the MA triad tends to originate distal to a line between the RS and MP triads in *T. lotis* but on or close to the line in *T. lacustris* (pl. 5). Tillyard (1933) suggested that the humeral projection of the costal margin of the hindwing of *T. lacustris* is more rounded and irregular than the angular projections of *T. nigrescens* or *T. lacus-coerulei*. However, this feature varies widely amongst individuals and the distinction is subtle, with slight irregularity often evident in both mainland *Tasmanophlebia* (sp. AV2) and *T. lotis* (pl. 5). The comparison is also confounded by apparent wide variability in the shape of the hindwing among the mainland specimens (pl. 5 and fig. 1c).

As adults, the described species are more readily distinguished on the basis of colouration and genital morphology. Adult *T. lotis* and *T. lacustris* are broadly similar in body colouring (overall black or dark red-brown with pale annulations on the posterior edge of the abdominal segments, black thoraxes, generally darker dorsally than ventrally). Males can be distinguished on the basis of eye colour (brown dorsally in *T. lotis*, tan dorsally in *T. lacustris*) and by wing colour. The pattern of wing pigmentation is similar in the two species, but darker in *T. lacustris*. In *T. lotis*, the costal half of the hindwing is

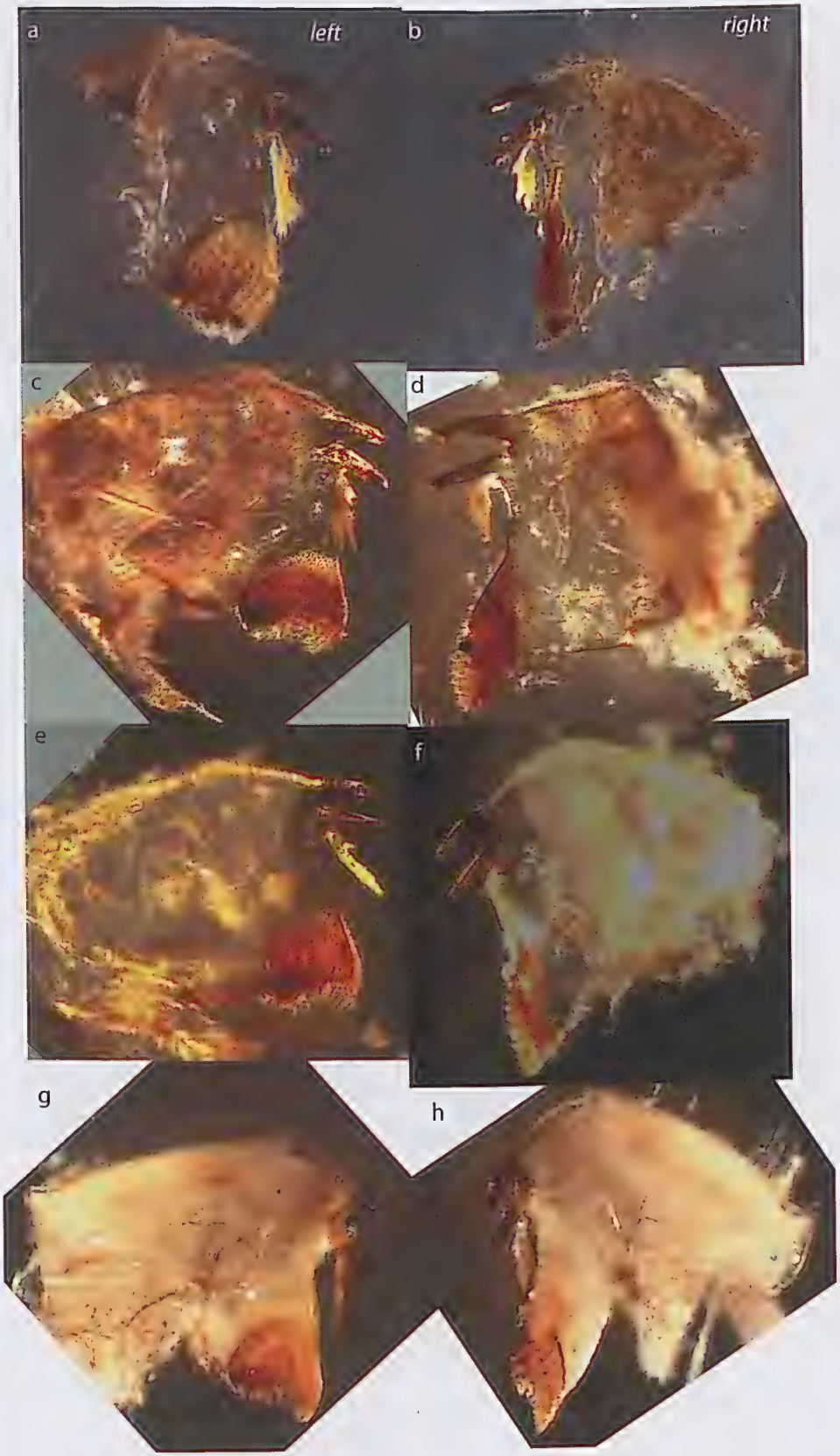

PLATE 3 — Left and right mandibles of (a, b) *Tasmanophlebia lotis* (Hellyer River, Tas.); (c, d) *T.* sp. AV2 (Swampy Plains River, NSW); (e, f) *T. lacustris* (Little Pine Lagoon, Tas.); and (g, h) *T. lacus-coerulei* (Blue Lake, NSW).

PLATE 4 — Nymphs of (a) *Tasmanophlebia lotis*, (b) *T. lacustris* (both live) and (c) *T.* sp. AV2 (specimen preserved in 90% ethanol).

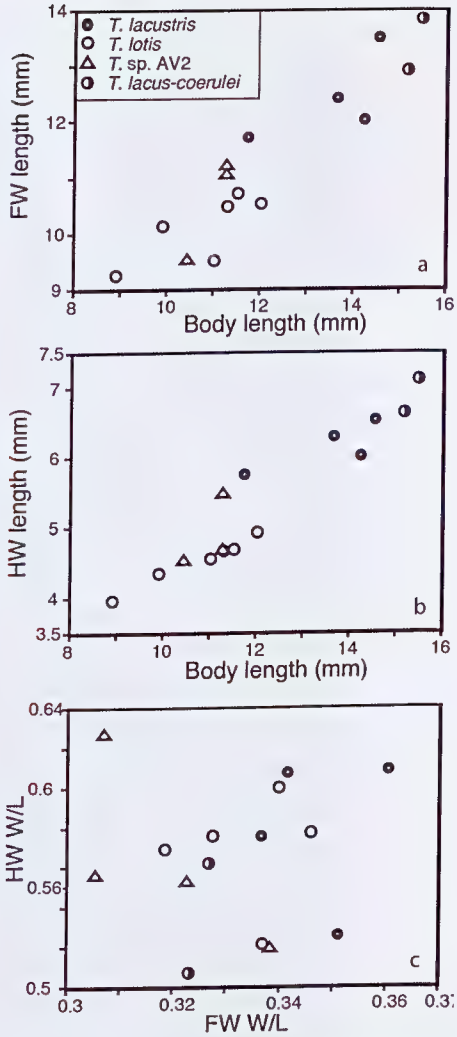

FIG. 1 — Relationships between forewing (FW) and hindwing (HW) dimensions (width and length) and body length in the Australian *Tasmanophlebia* spp.

pale yellow, whereas in *T. lacustris* it is a dark brown and blends at its dorsal tip into the pigmented pterostigma of the forewing to form a continuous oblique band across the two wings (pl. 5). Adult male *T. nigrescens* are uncommon in collections, but Tillyard (1933) reports the thorax and abdomen of the male imago as black with no obvious patterning. Tillyard (1933) further reported the adult male *T. lacus-coerulei* as broadly brown, with a pattern of brown stripes on the abdomen. The fore and hindwings of imagoes of *T. lacus-coerulei,* as well as the mainland *T.* sp. AV2, are both largely colourless, other than a darkening along the leading edge of the forewing in both species and a darkening of the pterostigma in *T.* sp. AV2, the latter similar to that in *T. lotis* (pl. 3). The forewings of sub-imagoes of all four species tend towards a pale diagonal band proximal to a darker wing tip, though the feature is highly variable and often not prominent in *T. lacustris*. The hindwings of the sub-imagoes in all species but *T. lacus-coerulei* are uniformly greyish brown; that of *T. lacus-coerulei* has a distinctive brown posterior margin (pl. 5).

Male genitalia in the three described species, as well as *T. lotis* and *T.* sp. AV2, consist of a pair of hollow tubes fused along a long base and then dividing at the tip, looking like the letter "Y". The species differ in the shape of the genital lobes and apices. In an alcohol-preserved Tillyard specimen at the ANIC, the genitalia of a *T. lacus-coerulei* imago is broadly rounded at its apex and the lobes are narrowly divergent (pl. 2), consistent with Tillyard's (1933) description. In the other three species, the genital lobes are more strongly divergent. In *T. lacustris*, the wide angle is combined with bluntly rounded apices and large, round ventrally opening sperm ducts (pl. 2). Riek (1955) notes that the genitalia of male imagoes of *T. nigrescens* differ slightly from that of *T. lacustris*, but does not specify the differences. In both *T. lotis* and *T.* sp. AV2, the sperm duct openings are smaller and apices narrowly rounded (more so in *T.* sp. AV2 than *T. lotis*). The genital lobes of *T.* sp. AV2 are basally more widely divergent than in *T. lotis* and the tips straighter, such that the genitalia looks more like a "U" in *T.* sp. AV2 and a "V" in *T. lotis* (pl. 2).

Suter & Webb (2012) provided a dichotomous key to the nymphs of two previously described species of *Tasmanophlebia* (*T. lacus-coerulei* not included), as well as four undescribed species. The latter group includes *T. lotis* (as *Tasmanophlebia* sp. D). Principle diagnostic features

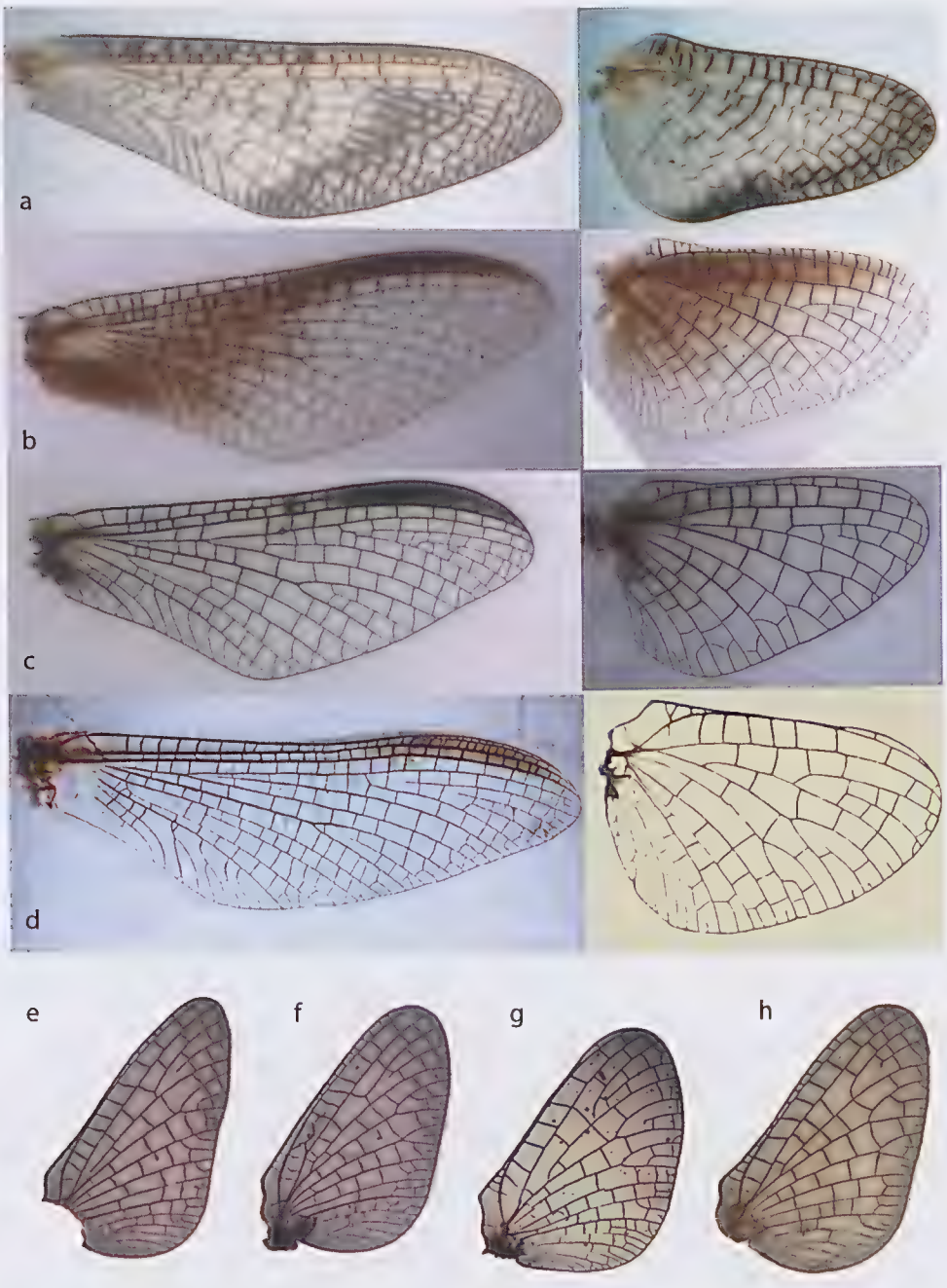

PLATE 5 — Top: Fore and hind wings of (a) *Tasmanophlebia lacus-coerulei* male sub-imago, Blue Lake, NSW; (b) *T. lacustris* male imago, Little Pine Lagoon; (c) *T. lotis* male imago, South Esk River; and (d) *T.* sp. AV2 male imago, Swampy Plains River, NSW. Hind wings of male imago *T.* sp. AV2 from (e) the Swampy Plains River, NSW, (f) Kiewa River, Victoria, and (g) Ovens River, Victoria, compared with that of (h) *T. lotis* (South Esk River, Tasmania).

are pigmentation and the extent of the abdominal dorsal crest. Consistent with Suter & Webb (2012), among specimens I examined the crest in *T. lotis* spans segments 2–8, as compared to *T. lacustris*, in which the dorsal spine on segment 6 is reduced and that on segments seven and eight very reduced or, more often, absent. Among other taxa, Suter & Webb (2012) indicate *T. nigrescens* and undescribed sp. C both lack the spines on segments seven and eight that are present in *T. lotis*, and the undescribed sp. AV2 (and *T. lacus-coerulei*) has a prominent spine on segment 1 that is lacking in *T. lotis*. Diagnostic features between *T. lotis* and the undescribed mainland sp. AV1 are not yet available. Differences amongst *T. lotis*, *T. lacustris*, *T. lacus-coerulei*, and *T.* sp. AV2 in the shape of the mandibles are noted above.

Material examined: Nymph exuviae, Mountain R., Tas., 6 March 2002; F imago, nymph exuviae upper So. Esk R., 28 Dec 2001; F sub-imago, Styx R., Tas. 24 March 1988; nymph, So. Esk R., Mathinna, Tas., 7 Jan 2002; nymph, Brid R., Tas., 16 Oct 2004; F imago, Mountain R., Tas. March 2002; nymph Mountain R., Tas., 8 March 2002; F imago So. Esk R., Mathinna, 7 Jan 2002; nymph, upper Hellyer R., Tas., 30 Dec 2015; nymph exuviae, Hellyer R., 6 April 2002; M imago, Ringarooma R., Derby, Tas., 5 Feb 2005; M imago, Nive R., Tas., 11 Feb 1986; M imago, Mountain R., Tas., 9 March 2002; M imago, Huon R., Tas., 16 Jan 2004; nymph, Huon R., Tas., 29 Dec 2003; nymph exuviae, Lake Dobson, Tas., 9 Feb. 2006; MoV specimens: nymphs, Douglas Creek, Tas.; nymphs, Isis R., Tas.

GENETIC ANALYSIS

CO1 sequence data for *T. lotis*, *T. lacustris*, *T. lacus-coerulei* and *C. giganteus* have been archived in Genbank (BankIT954250 Seq1 KX868576–Seq 10 KX868585). Differences in nucleotide sequences among the examined oniscigastrid species were slight. Among the specimens examined, nucleotide sequences averaged 707 bases, which combined with the Suter & Webb material to produce a consensus CO1 sequence of 643 bases. The nearest-neighbour tree produced four closely related, but distinct groupings of specimens (fig. 2). The phylogeny suggests two major branch points: *T. lacus-coerulei* is a sister group to the other three species of *Tasmanophlebia*, separating

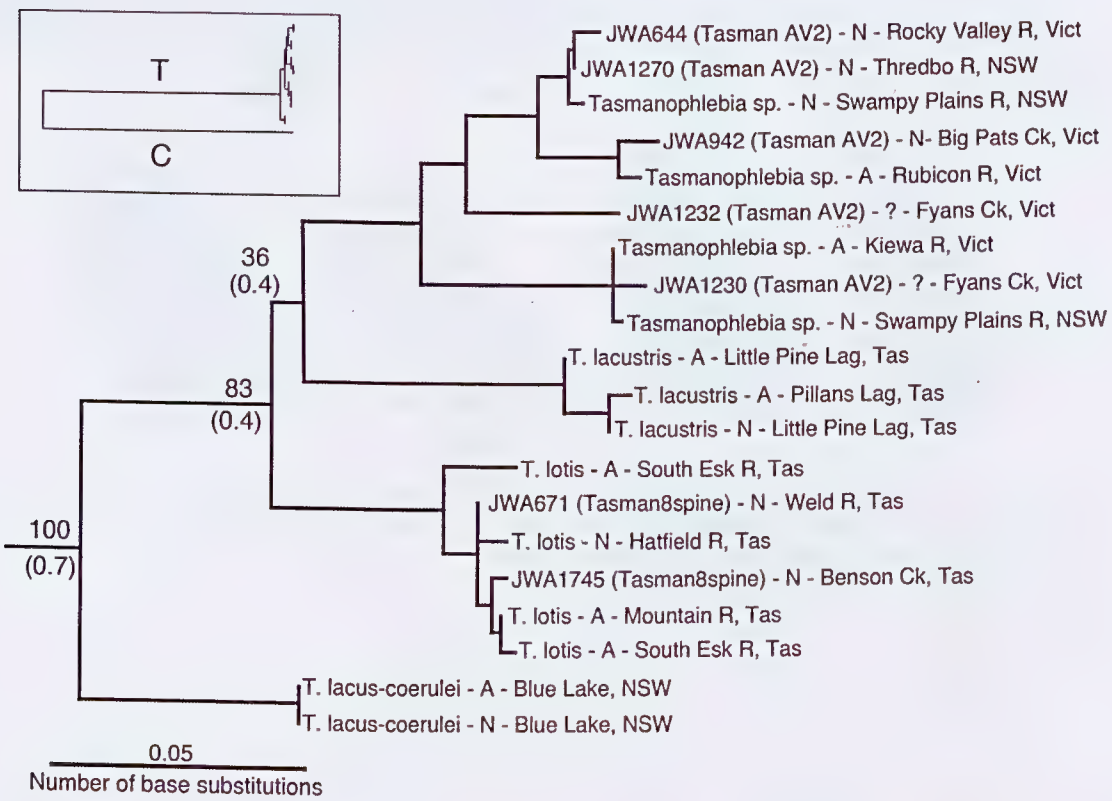
T
C
JWA644 (Tasman AV2) - N - Rocky Valley R, Vict
JWA1270 (Tasman AV2) - N - Thredbo R, NSW
Tasmanophlebia sp. - N - Swampy Plains R, NSW
JWA942 (Tasman AV2) - N- Big Pats Ck, Vict
Tasmanophlebia sp. - A - Rubicon R, Vict
JWA1232 (Tasman AV2) - ? - Fyans Ck, Vict
Tasmanophlebia sp. - A - Kiewa R, Vict
JWA1230 (Tasman AV2) - ? - Fyans Ck, Vict
Tasmanophlebia sp. - N - Swampy Plains R, NSW
T. lacustris - A - Little Pine Lag, Tas
T. lacustris - A - Pillans Lag, Tas
T. lacustris - N - Little Pine Lag, Tas
T. lotis - A - South Esk R, Tas
JWA671 (Tasman8spine) - N - Weld R, Tas
T. lotis - N - Hatfield R, Tas
JWA1745 (Tasman8spine) - N - Benson Ck, Tas
T. lotis - A - Mountain R, Tas
T. lotis - A - South Esk R, Tas
T. lacus-coerulei - A - Blue Lake, NSW
T. lacus-coerulei - N - Blue Lake, NSW
36
(0.4)
83
(0.4)
100
(0.7)
0.05
Number of base substitutions

FIG. 2 — Molecular phylogenetic analysis (CO1) time tree based on the Maximum Likelihood method, for *Tasmanophlebia* specimens collected in Tasmania, Victoria and NSW, plus as an out-group, a nymph of *Coloburiscoides giganteus* (box). Suter & Webb specimens are indicated by specimen number (JWA...); they identified their mainland specimens as *T.* sp AV2. Numbers at the major branches indicate the proportion of events in a bootstrap test of phylogeny (500 replicates) in which the two branches clustered together and, in parentheses, the relative time of separation. The tree is drawn to scale, with the branch lengths measured in the relative number of substitutions per site. A = adult (sub-imago), N = nymph, ? = life history stage of specimen not specified.

earliest in the phylogeny, followed by a nearly, if not actually, concurrent separation of *T. lotis* and *T. lacustris* from the other sampled mainland *Tasmanophlebia*. The specimens I collected in lowland rivers in Victoria and NSW, and illustrate in the plates, group with and appear to be conspecific with Suter & Webb's (2012) *Tasmanophlebia* sp. AV2 (fig. 2). Genetically, *T. lotis* is most similar to *T.* sp. AV2 (average number of base substitutions 0.092) and most different from *T. lacus-coerulei* (0.117). Differences within species are slight for *T. lacus-coerulei* (mean number of base substitutions 0), low for *T. lacustris* and T. *lotis* (0.01 and 0.014, respectively) and much higher for *T.* AV2 (0.054). As expected from a genetic analysis, adults and nymphs group together within species. Also as expected, the specimen of *Coloburiscoides giganteus* used as an outgroup for the analysis is clearly separated genetically from *Tasmanophlebia*.

ECOLOGY AND BEHAVIOUR

The geographic and habitat distributions of the two Tasmanian species appear to be largely, if not completely, non-overlapping. In extensive sampling over Tasmania spanning the past 28 years, I have found *T. lacustris* only in lakes, ponds and pools in rivers on and close to the Tasmanian Central Plateau (fig. 3), where it is abundant. The exception is a single specimen collected at Arthurs Lake, a lower-altitude impoundment near the Central Plateau, in 1987. I have not seen the species there since. Tillyard (1935) reported *T. lacustris* from Lake Echo and, abundantly, Penstock Lagoon, also mid-altitude impoundments, based on collections in the 1930s and 1940s, but I have not found the species at either location. Riek (1955) also reports the species present in Lake Dobson, in the sub-alpine highland of Mount Field National Park. However, nymph exuviae collected on rocks along the margin of Lake Dobson in 2012 are attributable to *T. lotis*, based on abdominal spination. Otherwise, *T. lotis* is widely distributed in usually fast-flowing, cobble and gravel-filled streams and rivers in lowland Tasmania (fig. 3). Its presence in Lake Dobson reflects a preference for this habitat; although a "lake", Lake Dobson is essentially a large cobble pool at the head of a stream at Mount Field. In the same way, the presence of *T. lacustris* in slow-flowing pools and pondages in rivers on the Central Plateau reflects its essentially lacustrine habitat preferences. Neither species appears to be present in the rocky, sub-alpine ponds and lakes in the Hartz Mountain National Park (SE Tasmania), based on the absence of the usually conspicuous nymph exuviae during mid- and late summer collecting trips that span several years.

Tasmanophlebia lacustris nymphs are conspicuous and often very abundant in soft sediment habitats on the Central Plateau, where they form irregular lines in the sediment as they plough through it while feeding. Disturbed, they swim vigorously for short distances by undulating their bodies vertically. Not surprisingly, given their abundance, they are a major component of trout diets in these lakes. Nymph exuviae are extremely common on emergent rocks, vegetation, tree branches and other debris along the edges of the pondages, though the nymphs also frequently emerge by crawling directly onto muddy lake margins, where they transform into sub-adults. Imagoes have been observed in mating swarms at Little Pine Lagoon, Tin Hut Lagoon, Lake Ada and Ada Lagoon, in all cases in mid- to late summer (January to March) and late in the afternoon or in the evening. This seasonality is narrower than reported for alpine NSW *Tasmanophlebia* spp. by Campbell (1986), with adults recorded from September to March; Campbell suggested there may be more than one generation per year. Adult *T. lacustris* are relatively weak flyers, and occur in groups of approximately 10–30 individuals drifting back and forth horizontally around and over prominent bushes and other landmarks. At Tin Hut Lagoon and Lake Ada, the swarms were tens

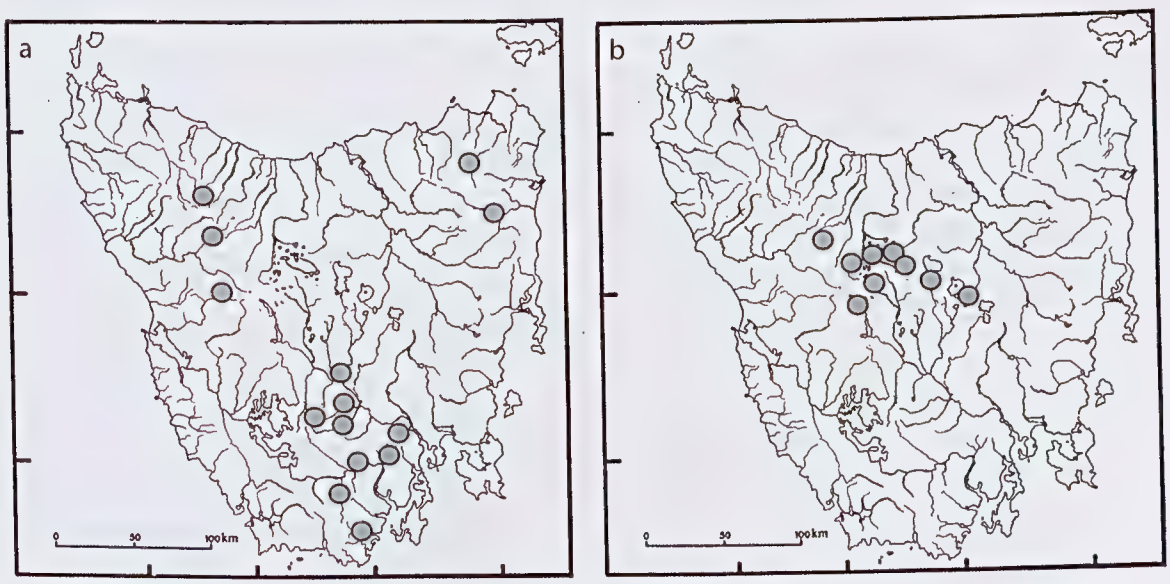

FIG. 3 — Locations where the author has collected (a) *Tasmanophlebia lotis* and (b) *T. lacustris* in Tasmania.

of metres from the shorelines. At dusk on 22 January 2016, I observed hundreds of swarms and thousands of *T. lacustris* "spinning" over bushes up to 40–50 m back from the edges of Lake Ada and Ada Lagoon. On several occasions, I have also found numerous spent female *T. lacustris* along lake margins early in the morning, consistent with dusk and nocturnal mating and egg-laying.

I have observed swarming behaviour of *T. lotis* on only one occasion, on 13 March 2009, along the rocky edges of the South Esk River near Mathinna (NE Tasmania). Solitary and small groups of adult males were seen flying in short horizontal excursions close to the ground, occasionally up to about 1 m high, along the shoreline in late morning and early afternoon. As in *T. lacustris*, they were noted to be relatively weak fliers, easily collected. Adults and sub-adults of the species are recorded in my field records from late December to early April, with most observations in February. The behaviour of the nymphs is similar to that of *T. lacustris*, typically observed "bull-dozing" through soft sediments. Emergence, as in other species in the genus (Campbell 1986), takes place by the nymph crawling out onto rocks and debris.

DISCUSSION

A comparison of the morphology and meristics of the Tasmanian lowland material with published descriptions, museum specimens and live caught material of *T.* sp. AV2 from Victorian and NSW rivers indicated broad overlap in most features between the mainland and Tasmanian samples, but also differences in hind wing shape (more triangular in Tasmania), mandible (narrower and more pointed grinding plate) and colour of the nymph (a characteristic spotting pattern on the ventral abdomen of Tasmanian specimens, uncommon among mainland samples). These differences suggested at least sub-speciation between the Tasmanian and mainland specimens. This hypothesis was tested by a CO1 genetic analysis, which was expanded to include *T. lacustris* and *T. lacus-coerulei*. The results strongly suggest the Tasmanian lowland specimens constitute a species separate from, but ecologically and morphologically similar to mainland, low elevation *Tasmanophlebia* spp.

Riek (1955) reported three species of *Tasmanophlebia* in Australia, two (*T. lacus-coerulei* and *T. nigrescens*) found on the Australian mainland and one (*T. lacustris*) endemic to highland areas of Tasmania. He subsequently (1970) listed four species (see also Hubbard & Campbell 1996), the addition possibly relating to a specimen subsequently collected in South Australia by Suter (1986). Riek (1955) also noted the similar morphology of *T. nigrescens* and *T. lacustris*, and speculated that the insects may be conspecific. Most recently, Suter & Webb (2012) suggested at least six species of *Tasmanophlebia*, based on nymph morphology and distributions, two of which occur in Tasmania.

The genetic analysis confirms *T. lacus-coerulei* is a sister clade to the other members of the genus, but also documents roughly equivalent levels of separation, based on nucleotide substitutions, amongst *T. lotis*, *T.* sp. AV2, and *T. lacustris*. The separation between the latter three species is reinforced by slight but consistent morphological differences among the three both as adults and nymphs and, for the Tasmanian pair, prominently non-overlapping habitat preferences. The genetic, morphological and ecological evidence supports an hypothesis of reproductively isolated populations. The first two lines of evidence also suggest significant heterogeneity among mainland *T.* sp. AV2, in the form of relatively high levels of genetic diversity among specimens and conspicuous differences in hindwing shape. The South Australian specimens of *Tasmanophlebia* reported by Suter (1986) appear to be *T.* sp AV2, based on a prominent dorsal spine on the first abdominal segment.

More generally, identification of *T. lotis* as a valid species is consistent with the suggestion of Hughes *et al.* (2011) that genetics would reveal a number of such cryptic taxa among Australian mayflies. The nearly, if not actually, identical relative time to separation between *T.* sp. AV2, *T. lacustris* and *T. lotis* suggests a split between the mainland riverine species and a Tasmanian population that quickly separated into a highland, lentic and lower elevation riverine species. Lack of a calibration date for the genetic analysis precludes estimating actual divergence times at this stage, but the differences amongst the *Tasmanophlebia* species parallel genetic (CO1) evidence of similar pairs of mayfly species in the genus *Offadens* (Baetidae) that are also found on both sides of Bass Strait (Webb & Suter 2011). The magnitude of sequence differences in the Baetids suggests separation of these sister taxa well before the Holocene flooding of Bass Strait following deglaciation (Webb & Suter 2011), which also could be the case in *Tasmanophlebia*.

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REFERENCES

Campbell, I.C. 1986: Life histories of some Australian Siphlonurid and Oligoneurid mayflies (Insecta: Ephemeroptera). *Australian Journal of Marine and Freshwater Research* **37**: 261–288.

Folmer, O., Black, M., Hoeh, W., Lutz, R. & Vrijenhoek, R. 1994: DNA primers for the amplification of mitochondrial cytochrome c oxidase subunit 1 from diverse metazoan invertebrates. *Molecular Marine Biology and Biotechology* **3**(5): 294–299.

Grewe, P., Krueger, C.C., Aquadro, C.F., Bermingham, E., Kincaid, H.L. & May, B. 1993: Mitochondrial DNA variation among lake trout (*Salvelinus namaycush*) strains stocked into Lake Ontario. *Canadian Journal of Fisheries and Aquatic Sciences* **50**: 2397–2403.

Hebert, P.D.N., Ratnasingham, S. & deWaard, J.R. 2003: Barcoding animal life: cytochrome c oxidase subunit 1 divergences among closely related species. *Proceedings of the Royal Society of London B* (Suppl.): DOI 10.1098/rsbl.2003.0025.

Hubbard, M.D. 1990: *Mayflies of the World, A catalog of the family and genus group taxa (Insecta: Ephemeroptera).* Flora & Fauna Handbook No. 8, Sandhill Crane Press, Gainesville, Fla. USA: 119 pp.

Hubbard, M.D. & Campbell, I.C. 1996: Catalogue of the Australian mayflies, recent and fossil (Insecta: Ephemeroptera). *Special Publications of the Australian Society of Limnology* 11: 43 pp.

Hughes, J.M., Huey, J.A., McLean, A.J. & Baggiano, O. 2011: Aquatic insects in eastern Australia: a window on ecology and evolution of dispersal in streams. *Insects* **2**: 447–461.

Kumar, S., Stecher, G. & Tamura, K. 2016: MEGA7: molecular evolutionary genetics analysis version 7.0 for bigger data sets. *Molecular Biology and Evolution* **33**: 1870–1874.

Riek, E.F. 1955: Revision of the Australian mayflies (Ephemeroptera). 1. Subfamily Siphlonurinae. *Australian Journal of Zoology* **3**: 266–280 plus plate.

Riek, E.F. 1970: Ephemeroptera (mayflies). *In: The Insects of Australia.* Melbourne University Press, Parkville, Victoria, Australia: 224–240.

Scholes, D. 1961: *Fly-fisher in Tasmania.* Melbourne University Press, Parkville, Victoria, Australia: 208 pp.

Suter, P.J. 1980: The taxonomy and ecology of the Ephemeroptera (mayflies) of South Australia. Unpublished PhD thesis, University of Adelaide.

Suter, P.J. 1986: The Ephemeroptera (mayflies) of South Australia. *Records of the South Australian Museum* **19**: 339–397.

Suter, P.J. & Webb, J. 2012: Key to the mature nymphs of *Tasmanophlebia* (Ephemeroptera: Oniscigastridae). Paper presented at the Taxonomy Research and Information Network (TRIN) Taxonomic Workshop held 31 January–1 February 2012, La Trobe University, Albury-Wodonga, January 31–1 February.

Tamura, K., Battistuzzi, F.U., Billing-Ross, P., Murillo, O., Filipski A. & Kumar, S. 2012: Estimating divergence times in large molecular phylogenies. *Proceedings of the (US) National Academy of Sciences* **109**: 19333–19338.

Tamura, K. & Nei, M. 1993: Estimation of the number of nucleotide substitutions in the control region of mitochondrial DNA in humans and chimpanzees. *Molecular Biology and Evolution* **10**: 512–526.

Tillyard, R.J. 1921: A new genus and species of mayfly (order Plectoptera) from Tasmania, belonging to the family Siphlonuridae. *Proceedings of the Linnean Society of NSW* **46**: 409–412.

Tillyard, R.J. 1933: The mayflies of the Mount Kosciusko region. 1. (Plectoptera). *Proceedings of the Linnean Society of NSW* **58**: 1–32.

Tillyard, R.J. 1935: The trout food insects of Tasmania, Part II – a monograph of the mayflies of Tasmania. *Proceedings of the Royal Society of Tasmania* **1935**: 23–59 plus plate.

Webb, J.M. & Suter, P.J. 2011: Identification of larvae of Australian Baetidae. *Museum Victoria Scientific Reports* **15**: 1–39.

(Accepted 4 October 2016)

Appendix

OTHER MATERIAL EXAMINED

T. lacustris: M and F imagoes and sub-imagoes, Little Pine Lagoon, Tas., 16 Jan 2003; M and F imagoes, nymphs Little Pine Lagoon, 3 Jan 2003; nymphs, unnamed pond near Pillans Lake, 24 Nov 2005; M and F sub-imagoes and imagoes, Ah Chees Lake, Tas., Jan 1988; nymph, Carter Lakes, Tas., 3 Feb 2004; nymph exuvia, Lake St Clair, Tas., 10 March 2016; M and F sub-imagoes and imago, First Bar Lake, Tas., 28 Jan 1998; nymph, Pine Tier Lagoon, Tas., 1 March 1987; F imago, Lake Augusta, Tas., 5 March 1990; nymph exuvia, Lake St Clair, Tas., 10 Jan. 2005; F sub-imago and nymph exuviae, Lake St Clair, 23 Feb. 1983; M sub-imago, Arthurs Lake, Tas., 1 March 1987; F imago, Lake Augusta, Tas., 8 March 1992; M and F sub-imagoes, nymphs, Deep Lake, Tas., 27 Jan 1991; M and F imago, Lake St Clair, Tas., 6 March 1988; F sub-imago Kay Lagoon, Tas., 22 Nov 1994; M and F sub-imagoes, Great Lake, Tas., 29 Jan 1995; M imago, Lake Augusta, Tas., 1 March 1992; M and F sub-imago, Lake Augusta, Tas., 26 Dec. 1982; M sub-imago, Christy's Creek, Tas., 9 Feb 2002; nymph exuviae, Ouse R. above Lake Augusta, Tas., 2 Feb. 2007.

T. sp. AV2: F imago and nymph, Swampy Plains R., NSW, 23 Feb 2006; M and F sub-imago, Ovens R., Vict., 23 Feb 2006; M imago and nymph exuviae, Rubicon R., Thornton, Vict., 24 Feb 2006; nymph exuviae, Kiewa R., Tawonga, Vict., 23 Feb 2006; MoV specimens: nymphs, Yarra R., Vict.; nymphs, Thougla Creek, Vict.; nymphs, Goulburn R., Vict.; nymphs, Watts R., Vict.; nymphs, Little Snowy Creek, Vict.; M imago, Little Snowy R., Eskdale, Vict., 20 Dec 1982; nymphs, Indi R., NSW. ANIC specimens: M and F sub-imagoes, Bolairo R., NSW, 13 Dec 1974; F sub-imago, Spencers Creek, NSW, 28 Jan 1930.

T. lacus-coerulei: M and F sub-imagoes and nymphs, Blue Lake, NSW, 22 Feb 2006; F sub-imago, Betts Creek, NSW, 22 Feb 2006. ANIC specimens: F imago and F sub-imago, Blue Lake, NSW; M sub-imago, Blue Lake, NSW.

SETTLEMENT AND SWIFT PARROTS — HISTORIC AND ONGOING HABITAT LOSS FOR A CRITICALLY ENDANGERED SPECIES (1788–2016)

by Debra L. Saunders and Tracey Russell

(with two figures and twelve plates)

Saunders, D.L. & Russell, T. 2016 (15:xii) Settlement and Swift Parrots — historic and ongoing habitat loss for a critically endangered species (1788–2016). *Papers and Proceedings of the Royal Society of Tasmania* 150(2): 55–73. ISSN 0080-4703. Fenner School of Environment and Society, Australian National University, Canberra, ACT, 0200 Australia (DLS*). School of Life and Environmental Sciences, The University of Sydney, Sydney, NSW, 2006 Australia (TR). *Author for correspondence. Email: debbie.saunders@anu.edu.au

The Swift Parrot, *Lathamus discolor* White, 1790, was among the first of Australia's birds to be scientifically described and illustrated following European settlement in 1788. Within 60 years of settlement, key habitat throughout the species' range was being lost. A unique compilation of historical and recent information on Swift Parrot habitat loss demonstrates how past events have rendered this species Critically Endangered. A crucial aspect of the loss of habitat is the speed and spatial extent over which it occurred. The most extensive loss happened during colonial times however, losses continue to this day due to various government land management policies and practices. Consequently, the Swift Parrot remains the subject of an ongoing national recovery program and its future is far from secure.

Key Words: Swift Parrot, *Lathamus discolor*, colonial art, migration, habitat loss, forestry, agriculture, development, legislation, climate change, conservation.

INTRODUCTION

Swift Parrots, *Lathamus discolor* White, 1790, are nectarivorous birds of the family Psittaculidae that have attracted much attention with their charismatic behaviour, melodious calls and colourful plumage (Gould 1848). The Swift Parrot forages on nectar and lerp in the woodlands and forests of southeastern Australia and migrates each year between breeding habitat in Tasmania and wintering habitat in southeastern mainland Australia (Juniper & Parr 1998) (fig. 1).

Although images of Swift Parrots from the late eighteenth and nineteenth century (e.g., pl. 1) provide an indication of their presence in habitats around Sydney and Hobart, further details on the natural history of this species were not available until John Gould (1848) published *The Birds of Australia and Adjacent Islands* (pl. 2). The valuable ecological information he provided, 50 years after the species was first described, included descriptions of food sources, flocking and foraging behaviour, and habitat.

Throughout the eighteenth and nineteenth centuries, information on abundance was limited to observations such as those by Gould (1848) who remarked on the great abundance of small flocks around Hobart. An interesting aspect of Swift Parrot migration, first noted in the early twentieth century, was its variability (Batey 1907) with large flocks appearing in response to abundant food resources into areas where they had been absent for years (Hindwood & Sharland 1964). Such variable habitat use has continued throughout the twentieth and twenty-first centuries (Saunders & Tzaros 2011). This includes large influxes of Swift Parrots in coastal habitats of New South Wales in the 1930s, 1950s (Hindwood & Sharland 1964) and 1960s (Bill Boyd pers. comm.) where flocks of up to 2000 birds were recorded as foraging at sites for up to three months, but then not seen again for many years.

FIG. 1 — Distribution of the Swift Parrot in southeastern Australia

Although these irruptions have previously been considered unpredictable (Hindwood & Sharland 1964), it now appears that they may be the result of extreme drought conditions in some parts of the species' range, as demonstrated more recently by Saunders *et al.* (2016).

Although the anecdotal nature of these records and the variability of habitat use by the species limit inference with regard to population trends, they provide valuable insights into the flocking behaviour and their irruptive nature in some years. For example during the 1966 influx the maximum flock sizes were up to three times those of the influx in 2002 when the largest flock of 650 birds were observed (pers. obs.) despite hundreds of targeted surveys in the area and across their range.

PLATE 1 — (a) Swift Parrot (*Lathamus discolor*) (c. 1789) by George Raper (Source: National Library of Australia, Canberra; reproduced with permission); (b) Birds by William Buelow Gould (1840s) (Source: Art Gallery of Ballarat, gift of Mr and Mrs Wallace White, 1980, Ballarat; reproduced with permission).

In the late twentieth century Brown (1989) provided a comprehensive report on the natural history of Swift Parrots, including further detailed information on habitat, food resources and the first assessment of population size, which was calculated as 1320 breeding pairs. These data provided a baseline to compare future population estimates and in the 1995/96 breeding season only 940 breeding pairs were detected, representing a severe decline (29%) (Saunders & Tzaros 2011). With a small population size, limited breeding range and ongoing threats to their habitat Swift Parrots were recognised as a threatened species in 1995, triggering the development of a recovery program (Brereton 1996).

Almost 20 years later, with fresh evidence of a rapidly declining population (Heinsohn *et al.* 2015), the species' status has now been revised as Critically Endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2015) as well as on the national *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Although a number of threats to this species have been identified (Brown 1989, Saunders & Tzaros 2011), habitat loss remains one of the most significant threats. However, historical information on the timing, extent and causes of this loss has not previously been examined. A greater understanding of the spatial and temporal extent of impacts on Swift Parrot habitat will result in an improved understanding of the factors impacting on remaining habitats and aid research and conservation management efforts (Lunt & Spooner 2005).

HISTORIC HABITAT LOSS (18th AND 19th CENTURIES)

Within 60 years of European settlement in Australia, habitat throughout the Swift Parrot's migratory range was being cleared. This was during Australia's exploitative pioneering era, when forests and woodlands were seen as an inexhaustible resource and the government supported progress, growth and development of the land without consideration of environmental effects (Frawley 1994). The loss of habitat extended from the Swift Parrot's breeding range in southeastern Tasmania, through to the wintering habitat across southeastern mainland Australia (fig. 2).

PLATE 2 — Swift Parrots in *Eucalyptus gibbosus* [now *Eucalyptus globulus*] from John Gould's (1848) book *Birds of Australia and Adjacent Islands* (Source: Australian National University Menzies Rare Book Collection, Canberra; reproduced with permission).

FIG. 2 — Key historic localities within the Swift Parrot range noted in this research.

NEW SOUTH WALES (EUROPEAN SETTLEMENT FROM 1788)

The first European colony was established in 1788 at Sydney Cove, within the wintering range of the Swift Parrot (fig. 2). To early pioneers, areas of native vegetation needed to be cleared to make the land productive (Cubit 1996) resulting in clearing for agriculture, grazing and timber resources (Carron 1985). One of the artists who painted Swift Parrots in the late eighteenth century, Thomas Watling, also did some drawings of the landscape around the colony, providing some insight into the extent and type of clearing of vegetation for the settlement. In general, large areas were entirely cleared of native vegetation, however, sometimes isolated old trees were left scattered around the edges of the settlement (pl. 3).

From first settlement to the end of the eighteenth century extensive, indiscriminate felling of timber trees occurred in a largely wasteful manner (Grant 1989) including areas known to contain habitat suitable for Swift Parrots. The extent of destruction of forested lands, such as those around the Nepean River, South Creek and George's River, prompted Governor Hunter to introduce the first timber regulations in 1795, although in reality they had little effect (Grant 1989). These areas were then included on a map of settlement growth districts in 1810 (pl. 4), and large areas of woodland containing Swift Parrot forage tree species continued to be cleared, despite further attempts to control such activity (Carron 1985). As a result, in 1898 it was noted that the once regularly occurring Swift Parrots around the Rooty Hill area of Sydney were now seldom seen (North 1898) (pl. 4).

In 1826, Governor Darling issued an order that selection and settlement of land was to be confined to a defined section of New South Wales. The "Limits of Location" were from Port Macquarie in the north to Moruya in the south and extending inland to the Liverpool Range and Yass (Wadham 1967, Grant 1989). Subsequently Swift Parrot habitat within both coastal and inland areas of the settlement limits was heavily impacted, e.g., John Gould first observed the species in its winter habitat in the Upper Hunter River district during a severe drought within an area that was extensively grazed by thousands of sheep and cattle (Datta 1997).

Coastal habitats within the specified limits would have been impacted upon concurrently by a number of settlements including Port Macquarie (1821) and Port Stephens (1826) on the north coast (Grant 1989) and Batemans Bay and Moruya (1820s) on the south coast (Turner 1996) (pl. 5). These settlements were established in areas that contain key forage tree species for Swift Parrots including Forest Red Gum *Eucalyptus tereticornis* Smith, Swamp Mahogany *Eucalyptus robusta* Smith, Spotted Gum *Corymbia maculata* Hill & Johnson and Blackbutt *Eucalyptus pilularis* Smith (Saunders & Tzaros 2011). As a result, within the first 50 years of European settlement, all major coastal habitat types known to be used by the Swift Parrot in New South Wales had been either cleared or altered to some extent.

PLATE 3 — North-West View taken from the Rocks above Sydney Cove in New South Wales, by Thomas Watling (1793–1795) for John White (Source: State Library of NSW; reproduced with permission).

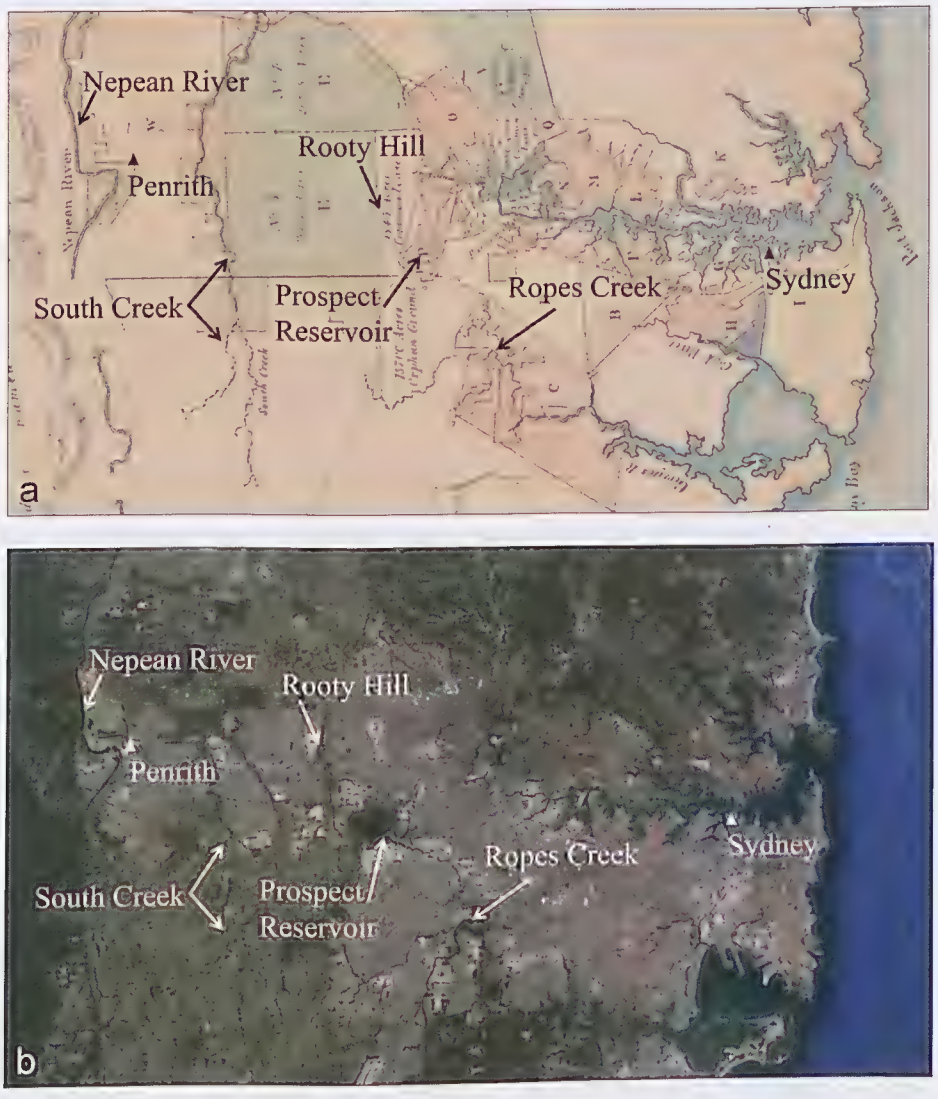

PLATE 4 — The Cumberland Plain area of western Sydney in (a) 1810, a new plan of the settlements in New South Wales: taken by order of Government, July 20th 1810, published by John Booth (1810), reproduced by William Dymock (1870–1899) (Source: National Library of Australia, Canberra; reproduced with permission) and (b) 2007, aerial photograph of Sydney showing extensive urban development across areas previously used by Swift Parrots (remnant habitats are small dark patches, large dark patch near Rooty Hill is Prospect Reservoir) (Google 2015).

Under regulations introduced in 1820, timber-getters needed permission to operate and remove specified quantities of timber. However, by 1870 the continued, unregulated felling of trees was considered a threat to future wood supplies and eventually resulted in the establishment of some of the first forestry reserves in New South Wales (Carron 1985).

The Liverpool Plains on the northwestern slopes of the Great Dividing Range marked the western boundary of the limits of settlement and were discovered by Europeans in 1823. The plains are among the most fertile and productive agricultural lands in Australia, and by 1831 squatters were establishing pastoral and agricultural areas (Halliday 2005). Squatters continued to spread across the western slopes of the Great Dividing Range to occupy extensive grazing areas beyond the specified limits (Grant 1989), gradually impacting on various types of grassy woodlands which included Swift Parrot forage tree species such as Mugga Ironbark *Eucalyptus sideroxylon* Woolls, White Box *Eucalyptus albens* Miquel, Grey Box *Eucalyptus microcarpa* Maiden and Yellow Box *Eucalyptus melliodora* A.Cunn. ex Schauer (Kennedy & Overs 2001, NSW Scientific Committee 2001, 2002, 2006, Saunders & Tzaros 2011). Grazing and clearing of native vegetation continued for much of the remainder of the nineteenth century with native vegetation being retained in increasingly small patches largely limited to travelling stock routes and road reserves (NSW Scientific Committee 2001) (pl. 6).

TASMANIA (EUROPEAN SETTLEMENT FROM 1803)

As the winter foraging habitats of Swift Parrots were being increasingly lost in New South Wales, the establishment of Hobart Town in 1803 resulted in additional loss of habitat in the heart of the Swift Parrot breeding range on the Tasmanian east coast. In similar fashion to the expansion of the settlement at Sydney Cove, as soon as Europeans settled in Hobart, clearing of native vegetation occurred (Carron 1985). Timber-getting became an important activity, starting with the eucalypts around the Derwent estuary. This included the harvesting of Tasmanian Blue Gum *Eucalyptus globulus* Labill. and Brown-top Stringybark *Eucalyptus obliqua*, L'Herit. which are prized for their high quality timber (Carron 1985), and provide important breeding habitat for Swift Parrots (Saunders & Tzaros 2011).

The image of Hobart Town in 1868 (pl. 7a) illustrates the development of the Derwent River foreshore and the image of Derwent Park in the 1800s (pl. 7b) provides an example of clearing on the upper reaches of the Derwent River with Mt Wellington in the background, which was a popular area for collecting Swift Parrots (Gould 1848, Datta 1997). The loss of breeding habitat also occurred in other coastal settlement areas of eastern Tasmania, such as around the Port Arthur penal colony (established in 1830), on the south coast and on offshore islands where manufacturing enterprises such as ship building, blacksmithing and brick making were burgeoning and utilising timber from the surrounding forests (PAHSMA 2007). However isolated trees and some patches of native vegetation remained in the areas surrounding settlements, which would have continued to provide at least some limited foraging habitat for Swift Parrots (pl. 8).

The demands for timber, as well as cleared land for settlement, agriculture and grazing increased the pressure on Swift Parrot breeding habitat. By 1835, virtually all of the open grasslands and grassy woodlands of Tasmania had been occupied and given over to the production of wool and wheat. Legislation such as the *Waste Lands Act 1858* was devised to encourage this selection and development of forested areas for agricultural purposes. Although in the

PLATE 5 — Historic clearing of coastal forests near Tanja (Bega) (Unknown Photographer 1877–), on the south coast of New South Wales (Source: State Library of NSW, Sydney; reproduced with permission)

PLATE 6 (above)— Historical clearing of woodlands for agriculture on the western slopes of New South Wales with a narrow strip of trees retained in the background – '7ft high wheat crop on "Kia Ora", Grogan-Grogan, Temora area, NSW' (Unknown Photographer 1880–1940) (Source: State Library of NSW, Sydney; reproduced with permission).

PLATE 7 — (a) Hobart Town, from the tower of St David's Church by Hugh Munro Hull (1859) (Source: State Library of Tasmania, Hobart; reproduced with permission);
(b) At Derwent Park, New Town, V.D.L." by T.E. Chapman (1835–1860) (Source: State Library of Tasmania, Hobart; reproduced with permission).

1880s concerns began to be expressed about the cumulative impacts on Tasmanian forests from uncontrolled logging, land clearing and frequent and uncontrolled fires, these activities continued largely unchecked until the end of the century (Cubit 1996). Concerns were raised over the depleted timber resources and impacts to the Tasmanian Blue Gums in particular where it was noted that they could not survive repeated firing of the undergrowth (Innes 1896).

The Tasmanian Blue Gum, is an integral component of the Swift Parrot breeding habitat (Brown 1989) and measures to reduce such destructive forestry practices in Tasmania were not enacted until 1919 when Conservators of forests were appointed and the *Forestry Act 1920* was introduced (Cubit 1996).

VICTORIA (EUROPEAN SETTLEMENT FROM 1835)

Major habitat loss occurred again with the settlement of Melbourne in 1835. Within ten years, key habitat north of Melbourne was subject to rapid population increase (Powell 1969), including a core part of the Swift Parrot wintering range in central Victoria. This was followed by an even greater human population explosion, and corresponding destruction of native forests when gold was discovered in 1851 (Carron 1985) in the heart of the Swift Parrot winter habitat around Bendigo. Within eight years there were half a million people in Victoria (Commonwealth of Australia 2006a) and the demand for wood was voracious. This proved to be the most devastating loss of Swift Parrot habitat in the mid nineteenth century, and eliminated almost all old growth trees in the Box-Ironbark forests of Victoria (Environment Conservation Council 2001). Although legislation and licensing were eventually established, there were no restrictions on tree species, sizes or quantity of timber harvested (Carron 1985). The Box-Ironbark forests were extensively damaged during the gold rush period (Environment Conservation Council 2001) (pl. 9), with indiscriminate clearing of species such as Red Ironbark *Eucalyptus tricarpa* Hill & Johnson, Mugga Ironbark *E. sideroxylon*, Grey Box *E. microcarpa*, Yellow Gum *Eucalyptus leucoxylon* Mueller, and Yellow Box *E. melliodora,* which provide vital habitat for Swift Parrots.

The extent to which the forests were being exploited, both legally and illegally, continued throughout most of the latter part of the nineteenth century (Victoria Parliament 1865, 1874) and evidence of this remains today with the almost complete absence of old growth trees (Environment Conservation Council 2001). The extent of unnecessary damage to the forests was highlighted in a report by Inspector-General Ribbentrop of the Indian Forest Service in 1896, which stated that the state forest conservancy and management in Victoria were in an extraordinarily backward state, with inadequate laws, funding, revenue and reserve establishment as well as rampant waste and destruction by fire (Ribbentrop 1896).

Given the extreme and rapid destruction of forests in Victoria, an attempt was made to curtail the reckless exploitation of native forests by appointing Conservators of Forests and establishing the *Forestry Act 1907* (Carron 1985). However, despite the large scale habitat clearance that occurred in the mid-1800s, in the early 1900s Batey (1907) noted that Swift Parrots were still frequent visitors to Yellow Box habitats.

ONGOING HABITAT LOSS (20th AND 21st CENTURIES)

In the twentieth century new concepts such as "wise use" management of natural resources were introduced, however the first half of this century was dominated by two world wars, post-war reconstruction and an economic depression. As a result, the utilitarian ethos of "progress through

PLATE 8 — Port Arthur 1844 by Tasmanian Lands Department (1917) (Source: Allport Library and Museum of Fine Arts, State Library of Tasmania, Hobart. Reproduced with permission).

PLATE 9 — Extensive habitat loss in central Victoria. (a) Diggings at Little Bendigo, Forest Creek, 1852 by S.T. Gill (1855) (Source: National Library of Australia, Canberra; reproduced with permission). (b) Mt Alexander 1852 by S.T. Gill (1874) (Source: National Library of Australia, Canberra; reproduced with permission).

development" continued to dominate the management of lands and forests (Frawley 1994). For example, the intensification of rural land settlement continued with little prior economic or environmental analysis, and forests continued to be cut at levels beyond long-term sustainability (Resource Assessment Commission 1990). However, in response to the growing conflict between environmental values and resource development in the 1960s, environmental protection and planning were progressively incorporated into state and federal government legislation (Frawley 1994).

The emphasis on environmental issues continued to grow over the next two decades with environmental strategies developed at national and international levels (IUCN *et al.* 1980, Commonwealth of Australia 1983), and the introduction of numerous pieces of environmental legislation at both national and state levels (Grinlinton 1990, Frawley 1994) throughout the Swift Parrot range. In the late 1980s, and throughout the 1990s environmental strategies became focused on Ecologically Sustainable Development principles (Ecologically Sustainable Development Steering Committee 1992), and legislation

was introduced for the protection of native vegetation and threatened species (e.g., Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act), NSW *Threatened Species Conservation Act 1995* (TSC Act), Tasmanian *Threatened Species Protection Act 1995; and Commonwealth EPBC Act* 1999) (Bates 2006). This included listing of the Swift Parrot as a threatened species at national and state levels.

Brown (1989) and Brereton (1996) identified habitat loss as the single largest threat to the Swift Parrot, and this continues to be the case into the twenty-first century (Saunders & Tzaros 2011) despite the introduction of legislative frameworks and recovery plans to protect the Swift Parrot. Although there have been some advances in the conservation of this species (Saunders *et al.* 2007), various land use practices such as forestry, agriculture, pastoralism, mining and urban development continue to impact this species' habitat (Saunders 2002, Marshall 2006, Saunders & Tzaros 2011, Allchin *et al.* 2013, Stojanovic *et al.* 2014).

The extent of habitat loss for the Swift Parrot has been so severe that a number of key habitats are now classified as endangered ecological communities with as little as 5–15% remaining (NSW Scientific Committee 1997, Commonwealth of Australia 2000, 2002, 2004, 2005). However, the value of these remnants remains high given they often provide the only foraging resources for the species within an otherwise cleared landscape (Saunders & Heinsohn 2008, Saunders *et al.* 2016). Since the original extent of Swift Parrot habitat and the subsequent habitat loss in each state has never been quantified, despite being a key action in the national recovery plan (Saunders & Tzaros 2011), there are currently no baseline data to fully understand the true extent of historic, current and ongoing habitat loss.

FORESTRY

Following on from the initial forestry Acts of the early twentieth century, various state forestry organisations were becoming more interested in a national outlook, with greater emphasis on the need for special forest legislation, permanent and inalienable reserves, and the creation of permanent management authorities with statutory powers (Carron 1985). Reserves were initially established to ensure future timber supplies, however, over time, other forest values, such as habitat value for threatened species, became more widely recognised (Frawley 1994).

Years of conflict and disputes occurred over the values and use of forests, resulting in the Australian government's attempt to resolve the issue by producing the National Forest Policy Statement (Commonwealth of Australia 1992). The statement included the establishment of Regional Forest Agreements (RFAs) which were intended as 20-year plans for the conservation and sustainable management of forests (Commonwealth of Australia 2008). Of the 10 RFAs established, nine have potential implications for Swift Parrot habitat. Although the RFA process substantially increased the total area of forest in conservation reserves (Commonwealth of Australia 2008), the protected areas were based upon forests that had already been impacted by many years of mismanagement, and the logging of old growth forest was still permitted in Tasmania (Bates 2006). It should also be noted that the RFA process generally did not deal with private lands or plantation forests, and was limited in terms of landscape scale conservation given it was implemented on a region by region basis. Therefore only limited Swift Parrot habitat was protected under the RFA and the old growth forests containing important nesting and foraging habitat continue to be cleared (Saunders & Tzaros 2011, Gramenz 2016). RFAs and associated licenses include detailed prescriptions for the retention and protection of threatened species habitats within timber harvesting areas, however they have proven to be largely inadequate for the Swift Parrot (Munks *et al.* 2004, Marshall 2006).

Swift Parrot habitat within production forests is afforded different levels of protection in different areas. Within key regions of Victoria, such as the Bendigo Forest Management Area, Swift Parrot Management Areas were established at 40 priority sites. In 2002, 23 of these sites were included in the conservation reserve system as part of the Box-Ironbark Investigation (Department of Natural Resources and Environment 2002a) (Environment Conservation Council 2001). A further seven sites were partially included in the conservation reserve system and the remaining 10 sites were retained within production forest (Environment Conservation Council 2001, Department of Natural Resources and Environment 2002a). Forestry operations within these remaining Swift Parrot Management Areas are required to retain all trees greater than 80 cm Diameter at Breast Height (DBH) as well as two trees per hectare for the remaining three tree size classes (60–80 cm, 40–60 cm and 20–40 cm), however, in other regions of Victoria the required level of habitat retention is less rigorous (Department of Sustainability and Environment 2003).

In NSW production forests, habitat protection is not required unless there are Swift Parrot records at a particular location. However, even when there are records, only 10 trees (with no specification of minimum size) need to be retained for every two hectares of net logging area (NSW Department of Primary Industries 1999). Despite increasing knowledge of the importance of winter habitat for Swift Parrots in production forests of NSW (Kennedy & Overs 2001, Saunders 2008) and repeated expert advice to amend the forestry prescriptions as the RFAs have come up for review (Saunders 2010), no suitable forestry prescription amendments have been made. On the western slopes of NSW however, a number of important remnant habitats that were previously state forests have incrementally been incorporated into the conservation reserve system over the past 15 years (e.g., Livingstone and Benambra National Parks created in 2001, Jindalee National Park in 2011).

However, of greatest concern are the ongoing impacts from timber harvesting practices in Tasmania, where the Swift Parrots are entirely dependent on old growth forest

for nesting during the breeding season (Voogdt 2006, Webb *et al.* 2012). Despite the growing knowledge of the species' breeding biology and ecological requirements (Stojanovic *et al.* 2012, Webb *et al.* 2014, Stojanovic *et al.* 2015) this habitat continues to be approved for clearing (Tasmanian Government 2005, Marshall 2006, Australian Government 2011, 2013, NSW Government 2013) despite directly conflicting with expert advice and the objectives of ecologically sustainable forest management (Pullinger 2015) (pl. 10). For example, Stojanovic *et al* (2014) clearly demonstrate the extreme cumulative impact on the Swift Parrot from forest management practices that reduce the amount of mature habitat available.

The Forest Practices Authority is an independent statutory body that administers the Tasmanian Forest Practices Code (FPC) on both public and private land. Its primary responsibility is regulating the management of forest vegetation with the objective of achieving sustainable management of public and private forests with a duty care policy for the environment (Forest Practices Authority 2015). However, concerns have been raised in relation to this duty of care policy with the commercial objectives of the FPC seen as contrary to sustainable forest management practices since it does not maintain "viable breeding populations and habitat for all species" (EDO 2015).

In addition, the FPA is responsible for controlling land clearing on public and private land in Tasmania. Under the Permanent Native Forest Estate Policy, broad-scale clearing and conversion of native forest on public land was phased out in 2010, however broad-scale clearing and conversion of up to 40 hectares of native forest per property each year remains permissible in 2016 (Tasmanian Government 2016). Between 1972 and 1999, over a quarter of a million hectares of native vegetation were cleared in Tasmania (Kirkpatrick & Dickinson 1982, Kirkpatrick 1991, Kirkpatrick & Mendel 1999). The amount of native vegetation approved for conversion to plantation or non-forest use was 38 550 hectares between 1999 and 2002 (Forest Practices Board 2000, 2001, 2002). However there is no single data source to report on land clearance and vegetation change in a systematic and consistent way for different land uses, vegetation types and tenures. Forest Practices Board data are used to provide a guide to forestry related clearance. However, these data are not mapped, do not include clearing occurring below thresholds of the Forest Practices System, and are not capable of monitoring illegal or incremental clearing. Clearance of vegetation communities for other uses such as housing is not measured or reported (Resource Planning and Development Commission 2003).

In addition to the direct impacts of habitat loss, as the amount of mature forest decreases due to timber harvesting, predation by the Sugar Glider, *Petaurus breviceps* Waterhouse, 1839 (an introduced pest in Tasmania) at Swift Parrot nests dramatically increases (Stojanovic *et al.* 2014). The extent of these impacts is so great that this species is now at imminent risk of extinction in the wild (Heinsohn *et al.* 2015). So, in the 100 years since forestry Acts were established in eastern Australia, forestry activities continue to have a severe impact on core areas of Swift Parrot habitat.

In relation to the protection of forests from 1996–2007, the Tasmanian government established the Protected Areas on Private Land Program (PAPL) and the Private Forest Reserves Program (PFRP) to extend the system of forest reserves on private land. This resulted in about 30 000 hectares of forested land protected by conservation covenants (Resource Planning and Development Commission 2003). Bird Life Australia's ongoing Woodland Birds for Biodiversity Program, in collaboration with the NSW Nature Conservation Trust, Victorian Trust for Nature, Tasmanian Land Conservancy and the NSW Saving Our Species program, has protected key habitat

PLATE 10a — Ongoing conservation issues for the Swift Parrot. Wielangta Forest broad-scale clear felling of old growth Swift Parrot breeding habitat (background) for conversion to younger "sustainable-harvest" plantation forest (foreground) (2007) (Photo: Debbie Saunders, private collection).

by securing conservation covenants on 2700 hectares of significant woodland habitat throughout the Swift Parrot range (Ingwersen & Tzaros 2011). To complement these conservation initiatives, a recent crowdfunded project has enabled the installation of hundreds of nest boxes for Swift Parrots on predator free islands in Tasmania in preparation for the 2016/17 breeding season. At the start of the first season since box installation, 25% of the nest boxes are being used by Swift Parrots, increasing the capacity of this declining population to improve their breeding success (O'Connor 2016).

AGRICULTURAL PRODUCTION

Economic development in southeastern Australia in the nineteenth century resulted in the over-clearing of agricultural areas (Beeton *et al.* 2006) and left native vegetation confined to small, isolated remnants (Lunt & Spooner 2005) (pl. 11). Many areas continued to be cleared of native vegetation while others suffer incremental loss of vegetation from management of the surrounding landscape, through senescence of old trees and reduced regeneration of new ones (Gibbons & Boak 2002).

A National Framework for the Management and Monitoring of Australia's Native Vegetation was established in 2001 (Natural Resource Management Ministerial Council 2000) and revised in 2012 (COAG Standing Council on Environment and Water 2012). This framework required a commitment from all Australian, state and territory governments to reverse the long-term decline in quality and extent of Australia's native vegetation cover, and encouraging the protection, rehabilitation and restoration of native vegetation. Although the level of commitment within most of the Swift Parrot range was an improvement on past management practices (Department of Primary Industries Water and Environment 2000, Department of Natural Resources and Environment 2002b, Commonwealth of Australia 2006b, Ministerial Review Committee 2006, Natural Resources and Water 2007), clearing of old growth habitat continues to be an issue in Tasmania (Tasmanian Government 2005, Pullinger 2015).

Impacts on Swift Parrot habitat in NSW have been so severe that only 5% to 30% of the original vegetation now remains, such as for Grey Box, *E. microcarpa,* and Grassy White Box, *E. albens,* woodland, and what is left is often degraded (NSW Scientific Committee 2002, 2006). With such extensive losses of habitat there is an increased risk that the remaining areas may fail to produce the necessary food resources in one year, which may lead to rapid population decline due to the accumulated extinction debt (Kuussaari *et al.* 2009). That is, before such extensive habitat losses occurred, the birds had a much greater chance of locating the food resources they needed each year.

Many of the woodland remnants that remain occur within the extensive Travelling Stock Route (TSR) network of crown land and have great ecological value within the agricultural landscape (DECCW 2009). However the future management of TSRs is currently being evaluated as part of the NSW Travelling Stock Reserve Planning Framework (NSW Government 2014). Each of the NSW Local Land Service regions will assess the values and priorities of their local reserves and develop plans for the most appropriate future management (NSW Local Land Services 2015).

Plate 10b — Swift Parrots by Janet Flinn (2006). Water colour painting commissioned for fundraising purposes to help conserve Swift Parrot breeding habitat in Wielangta Forest, Tasmania. (Source: Debbie Saunders, private collection).

However, the NSW government is also currently in the process of reforming biodiversity management laws, with the aim of improving the policy, legislative, institutional and financial framework for biodiversity conservation. The reforms are also aiming to cut red tape, facilitate ecologically sustainable development and conserve biodiversity across NSW (State of NSW 2014). However, concerns have been raised about various detrimental aspects of the proposed reforms including the replacement of the *Native Vegetation Act* 2003 with the Local Land Services Amendment Bill that has no ban on broad-scale clearing and no "maintain-or-improve" standard to ensure environmental outcomes which is likely to result in significant clearing increases in NSW. It is also seen to be heavily reliant on "offsetting" biodiversity impacts rather than preventing the impacts, and removes protections within the laws to prevent continued biodiversity decline (EDO 2016).

In Victoria, the Native Vegetation Management Framework (Department of Natural Resources and Environment 2002b) was established to achieve a reversal, across the entire landscape, of the long term decline in the extent

and quality of native vegetation. This is now being implemented through Property Vegetation Plans (PVPs) whereby landholders outline the future management of native vegetation on their property (Department of Sustainability and Environment 2006b), and identify how they will offset the negative environmental impacts of proposed clearing by managing other native vegetation for conservation (Ministerial Review Committee 2006). Incentives are also being provided to landowners for conservation management and restoration of native vegetation (Department of Natural Resources and Environment 2002b). This has the potential to provide a range of benefits for the long term sustainability of Swift Parrot habitat and similar arrangements have been established in other states as well (Department of Primary Industries Water and Environment 2000, Department of Natural Resources 2006, Ministerial Review Committee 2006, Environment Protection Authority 2007). These planning tools have the ability to integrate natural resource management imperatives to generate win-win outcomes for biodiversity protection and native vegetation retention. However, the effectiveness of these tools will depend largely on how they are implemented "on the ground" (Bates 2006).

In Tasmania, the key drivers of land clearance have changed over time. In the late 1960s to early 1970s, a rise in commodity prices for fine wool became a driver for clearing to expand pasture, and for the use of woodlands and dry forest areas for grazing. In the 1970s and 1980s, significant clearance of native vegetation occurred for agricultural purposes. Clearing was undertaken largely in dry eucalypt forests in the east and northeast of the State. In the 1970s and 1980s conversion from broad-scale sheep and beef enterprises to more intensive dairy farming took place, involving some further clearing to expand existing pasture (AGO 2000).

Given that many important areas of Swift Parrot habitat occur on private property throughout the species' range, where voluntary conservation agreements are established (Tasmanian Government 2009; NSW Office of Environment and Heritage 2013, Tasmanian Government 2015) the habitat is given valuable protection in perpetuity that may not have otherwise occurred (Saunders & Tzaros 2011). To complement these conservation initiatives, a long-term habitat protection and restoration project was recently funded by the NSW Environmental Trust. The project focuses on habitats within two priority regions of the species' winter range, and will commence on-ground works in 2017 across various tenure (NSW Office of Environment and Heritage 2016).

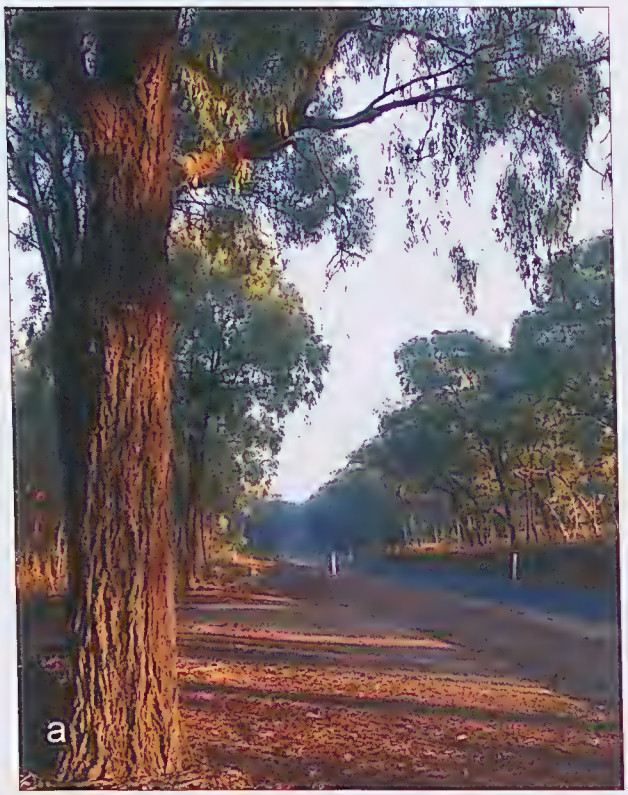

PLATE 11 — Remnant western slopes habitats. (a) Mates Gully Traveling Stock Reserve, near Tarcutta, New South Wales (2003) (Photo: Debbie Saunders, private collection). (b) Livingstone National Park, surrounded by agricultural land on the western slopes of New South Wales, was previously a state forest (2001) (Photo: Debbie Saunders, private collection).

URBAN, INDUSTRIAL AND MINING DEVELOPMENTS

The spread of towns and cities to accommodate Australia's growing population continues to the present day with ongoing clearing of natural ecosystems (Commonwealth of Australia 2006b), including habitat for the Swift Parrot. With much of Australia's urban development undertaken prior to the 1980s (Commonwealth of Australia 2006b), and prior to the introduction and enforcement of environmental legislation (Frawley 1994), a legacy of extensive urban development surrounding fragmented and degraded natural environments remains (pl. 12). In the 1990s more comprehensive legislation for the environment and threatened species were introduced throughout the Swift Parrot range (e.g., NSW TSC Act, Victorian FFG Act and Commonwealth EPBC Act).

Environmental Impact Assessment processes for developments included detailed evaluation of the significance of impacts on threatened species and endangered ecological communities at both the state and federal levels (Chapple 2001, Department of Sustainability and Environment 2006a, Department of Environment and Water Resources 2007). However, after a number of years of EPBC Act implementation, the referral, assessment, approval and offsetting processes have failed to achieve the environmental objectives (Macintosh 2004, Macintosh & Wilkinson 2005). This failure has often contributed to the "death by a thousand cuts" for biodiversity, in favour of economic development (Bates 2006). For example, the cumulative loss of Swift Parrot habitat continues to occur as a result of native vegetation clearing approvals for urban (Commonwealth of Australia 2002, 2007, NSW Government 2013), industrial (Saunders 2002, Commonwealth of Australia 2004, Group 2016) and mining developments (Australian Government 2004, 2011, 2013). As a result the decline of native species, including the Swift Parrot, and their habitats continues (Commonwealth of Australia 2009).

Biodiversity offsets are an increasingly popular yet controversial tool to deal with such losses in conservation. Their popularity lies in their potential to meet the objectives of biodiversity conservation and of economic development in tandem; the controversy lies in the need

PLATE 12 — Remnants and individual trees in urban areas are often the only habitat that remains on the central coast of New South Wales. (a) Swift Parrot foraging habitat at Penrith, on the Cumberland Plain of western Sydney 2005. (Photo: Debbie Saunders, private collection). (b) Urban mass roosting site at Charmhaven, Central Coast NSW with evidence of incremental loss of remnant vegetation for further housing (Photo: Debbie Saunders, private collection).

to accept ecological losses in return for uncertain gains. The offsetting approach is being widely adopted, even though its methodologies and the overriding conceptual framework are still under development (Bull *et al.* 2013). In NSW, BioBanking legislation was introduced in late 2006 with the aim of "no net loss" of biodiversity associated with development, particularly expanding urban and coastal development. However such biodiversity offset schemes have been found to be inconsistent in meeting conservation objectives because of the challenge of ensuring full compliance and effective monitoring and conceptual flaws in the approach itself (Burgin 2008, Bull *et al.* 2013). There is also a lack of supporting evidence for successful ecological restoration as a result of current offset policies (Maron *et al.* 2012).

The impacts of spreading urban development on the Swift Parrot have been most pronounced in coastal areas where 86% of Australia's human population now reside (Natural Resource Management Ministerial Council 2003). An example of such extensive habitat loss is illustrated by Forest Red Gum habitat on the central coast of NSW that only remains as individual trees scattered within an otherwise urban environment. Despite this, up to one third of the Swift Parrot population (650 birds, August 2002) have relied upon this urban habitat in some years, roosting and foraging in old trees in residential backyards (pers. obs.) (pl. 12). Furthermore, these impacts are likely to increase with growing pressure for extensive urban development along the southeastern coast of mainland Australia (winter habitat) and on the Tasmanian coastline (breeding habitat) (Commonwealth of Australia 2006b).

CLIMATE CHANGE

Anthropogenic climate change is another important conservation issue that has slowly gained recognition and support in policy, legislation and the broader community over the past twenty years (Allen Consulting Group 2005, Cowie 2007, Olsen 2007, IPCC 2014a). It has been established that climate change is affecting the phenology, physiology and distribution of numerous organisms, as well as the composition and dynamics of communities (Hughes 2000, Walther *et al.* 2002, Parmesan & Yohe 2003, Parmesan 2006). Within the Australasian region, long-term trends demonstrate higher surface air and sea surface temperatures, more hot extremes and fewer cold extremes, as well as changed rainfall patterns. The uncertainty in projected rainfall creates significant challenges for adaptation and has the potential for severe implications for natural ecosystems (IPCC 2014b).

For migratory species, the effects of climate change may vary both spatially and temporally in different parts of the migratory cycle, making adaptation particularly complex and challenging (Moller *et al.* 2004). As a small migratory bird, the Swift Parrot has been identified as one of Australia's most vulnerable bird species to climate change impacts (Garnett *et al.* 2013). Habitat availability for Swift Parrots has long been predicted to significantly decrease in response to climate change within both their wintering (Bennett *et al.* 1991) and breeding areas (Brereton *et al.* 1995). As a cool climate nesting species, the Swift Parrot is highly intolerant of excessive heat, and nestlings can, and often do, die from heat exhaustion (Laubscher 1999, Pollard 2000). Therefore, conditions within currently suitable nesting habitat are predicted to become less optimal for successful breeding and fledging as global warming increases, with almost a quarter of current Swift Parrot nesting habitat projected to become climatically unsuitable by the end of the twentyfirst century (Porfirio *et al.* 2016). Further investigation of the full potential impact of climate change on the Swift Parrot and its habitat has been identified as a priority research area in the EPBC Act Conservation Advice (TSSC 2016) and the National Recovery Plan (Saunders & Tzaros 2011).

As a nectarivore, the Swift Parrot is dependent on food sources directly influenced by climatic conditions such as rainfall and temperature (Law *et al.* 2000). With dry sclerophyll forests and woodlands predicted to experience increased temperatures over the next few decades (Dunlop and Brown 2008, Grose *et al.* 2010), this may lead to mismatches between the timing of migration and foraging habitat phenology within both breeding and non-breeding habitats. Such mismatches have been found to result in reduced fitness and survival in some migratory birds (Coppack *et al.* 2001, Coppack & Both 2002, Bairlein & Huppop 2004), although a diverse array of responses has been observed both in Australia and around the world (Lehikoinen *et al.* 2004, Gordo *et al.* 2005, Beaumont *et al.* 2006, Lehikoinen *et al.* 2006, Chambers 2008, Gordo & Sanz 2008). The only study to examine the timing of Swift Parrot migration was conducted 10 years ago (Beaumont *et al.* 2006) and found no significant change in arrival date for the breeding grounds, however it is likely that the spatially variable nature of Swift Parrot habitat use (Webb *et al.* 2012) and/or the concentration of observers within one part of this breeding range, may have masked shifts in the timing of migration. Changed seasonality of rainfall may also increase the frequency and severity of bushfires resulting in the loss of key habitats such as Tasmanian Blue Gum, as well as increased levels of eucalypt dieback (DPIPWE 2010).

Swift Parrot habitat use is negatively correlated with large, aggressive species such as the Noisy Miner *Manorina melanocephala* (Latham 1802), and Rainbow Lorikeet *Trichoglossus haematodus* Linnaeus, 1771 (Saunders 2008), and ongoing habitat loss and fragmentation together with climate change are likely to result in greater abundance of such opportunistic and invasive species (Low 2008). Therefore the extensive physiological demands already on the species to locate a combination of distant and seasonally variable food sources from increasingly fragmented habitats (Saunders 2008), may be exacerbated by increased levels of negative inter-specific interactions in the future. Furthermore, when affected by a combination of such stressors, the immune system of migratory species may also become depressed to such an extent that their health, and ability to successfully migrate, is reduced (Bairlein

& Huppop 2004, Hoye *et al.* 2007). The health and sustainability of forests and woodlands currently inhabited by the Swift Parrot may also be impacted since this species plays an important role in pollination of the tree species in which it forages (Hingston *et al.* 2004).

Although climate change impacts on the Swift Parrot and its habitat are becoming increasingly evident, the type and extent of these impacts will depend on the cumulative impacts from all threats to the species (Opdam & Wascher 2004, Pimm 2008, Felton *et al.* 2009) including habitat loss, predation, collisions with human made structures, competition, disease and illegal capture (Saunders & Tzaros 2011).

CONCLUSION

The combination of images and other historical information on Swift Parrots and their habitat from colonial to recent times, provides valuable insights into the spatial and temporal extent of impacts on the species over more than 200 years. It illustrates how Swift Parrots depend on forests and woodlands that have been sought after, and extensively cleared and altered by humans since the late eighteenth century, and reveals the ongoing vulnerability of this species despite recognition of its conservation significance for over twenty years (Brown 1989, Brereton 1996, Marshall 2006, Saunders & Tzaros 2011).

To ensure the conservation of Swift Parrots there is an urgent need to protect existing breeding and foraging habitat across a diversity of tenure in southeastern Australia; reduce the impact of Sugar Glider predation; better understand and manage all trophic levels of climate change impacts and to substantially increase habitat re-establishment throughout the species' range. Without strong direct action at all levels, from local landholders through to state and national government agencies responsible for managing this species and its habitat, the future of this species is far from secure.

REFERENCES

AGO 2000: Land clearing: a social history. Australian Greenhouse Office, Canberra.

Allchin, R., Kirkpatrick, J.B. & Kriwoken, L. 2013: On not protecting the parrot – the impact of conservation and planning legislation on an endangered species in Tasmania. *Journal of International Wildlife Law and Policy* **16**: 81–104.

Allen Consulting Group 2005: Climate Change Risk and Vulnerability. Promoting an efficient adaptation response in Australia. Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.

Australian Government 2004: Environment Protection and Biodiversity Conservation Act 1999 Referral Decision EPBC 2003/974. To construct and operate the expansion of the Carshalton Mine Complex at Bendigo, Victoria. Decision to approve the taking of an action. Canberra.

Australian Government 2011: Rocglen Coal Mine Extension Project, near Gunnedah, New South Wales (EPBC 2010/5502). Australian Government, Canberra.

Australian Government 2013: Ravensworth Operations Project EPBC 2010/5389. Australian Government, Canberra.

Bairlein, F. & Huppop, O. 2004: Migratory Fuelling and Global Climate Change. *In* Moller, A., Fiedler, W. & Berthold, P (eds): *Advances in Ecological Research*. **35**: 33–47. Academic Press, UK.

Bates, G. 2006: *Environmental Law in Australia*. LexisNexis Butterworths, Chatswood.

Batey, I. 1907: On fifteen thousand acres: its bird-life sixty years ago. *The Emu* **7**: 1–17.

Beaumont, L.J., McAllan, I.A.W. & Hughes, L. 2006: A matter of timing: changes in the first date of arrival and last date of departure of Australian migratory birds. *Global Change Biology* **12**: 1339–1354.

Beeton, R., Buckley, K.I., Jones, G.J., Morgan, D., Reichelt, R.E. & Trewin, D. 2006: Australia State of the Environment 2006. Department of the Environment and Heritage, Canberra.

Bennett, S., Brereton, R., Mansergh, I., Berwick, S., Sandiford, K. & Wellington, C. 1991: The potential effect of enhanced greenhouse climate change on selected Victorian fauna. Department of Conservation and Environment, Melbourne.

Brereton, R. 1996: The Swift Parrot Recovery Plan 1997 – 1999. Tasmanian Parks and Wildlife Service, Hobart.

Brereton, R., Bennett, S., Mansergh, I. 1995: Enhanced greenhouse climate change and its potential effect on selected fauna of south-eastern Australia: a trend analysis. *Biological Conservation* **72**: 339–354.

Brown, P.B. 1989: The Swift Parrot *Lathamus discolor* White: A report on its ecology, distribution and status, including management considerations. Technical Report. Department of Lands, Parks and Wildlife, Hobart.

Bull, J.W., Suttle, K.B., Gordon, A., Singh, N. & Milner-Gulland, E.J. 2013: Biodiversity offsets in theory and practice. *Oryx* **47**: 369–380.

Burgin, S. 2008: BioBanking: an environmental scientist's view of the role of biodiversity banking offsets in conservation. *Biodiversity and Conservation* **17**: 807–816.

Carron, L.T. 1985: *A History of Forestry in Australia*. Australian National University Press, Canberra: 355 pp.

Chambers, L.E. 2008: Trends in timing of migration of south-western Australian birds and their relationship to climate. *EMU* **108**: 1–14.

Chapman, T.E. 1835–1860. At Derwent Park, New Town V.D.L. Allport Library and Museum of Fine Arts, ADRI: AUTAS001124061300 State Library of Tasmania, Hobart). Watercolour painting on paper.

Chapple, S. 2001: The EPBC Act: one year later. *Environmental Planning and Law Journal (EPLJ)* **18**: 523–539.

COAG Standing Council on Environment and Water 2012: Australia's Native Vegetation Framework. Canberra.

Commonwealth of Australia 1983: A National Conservation Strategy for Australia: Living resource conservation for sustainable development. Australian Government Publishing Service, Canberra.

Commonwealth of Australia 1992: National Forest Policy Statement. Commonwealth of Australia, Canberra.

Commonwealth of Australia 2000: Commonwealth Listing Advice on Cumberland Plain Woodlands. EPBC Act List of Threatened Ecological Communities. Commonwealth of Australia, Canberra.

Commonwealth of Australia 2002: Environment Protection and Biodiversity Conservation Act 1999 Referral Decision EPBC 2002/711. Mirvac Homes subdivision, The Entrance Rd, Bateau Bay. Decision that action is not a controlled action. Commonwealth of Australia, Canberra.

Commonwealth of Australia 2004: Environment Protection and Biodiversity Conservation Act 1999 Referral decision EPBC 2004/1417. To develop the Hunter Economic Zone Industrial Estate, Hunter Valley, New South Wales. Decision to approve the taking of an action. Commonwealth of Australia, Canberra.

Commonwealth of Australia 2006a: Australian Historical Population Statistics. Population by sex, state and territories. 31 December, 1788 onwards. Cat. no. 3105.0.65.001. Commonwealth of Australia, Canberra.

Commonwealth of Australia 2006b: Australian State of the Environment 2006. Commonwealth of Australia, Canberra.

Commonwealth of Australia 2007: Environment Protection and Biodiversity Conservation Act 1999 Referral Decision EPBC 2007/3880. Avery Village Partnership/Residential development/Avery's Lane, Heddon Greta, Cessnock, 2 km NE of Kurri Kurri/NSW/Rezoning and Residential Development of Avery's Village, Cessnock, NSW. Decision approval not required – particular matter. Commonwealth of Australia, Canberra.

Commonwealth of Australia 2008: Regional Forest Agreements. Commonwealth of Australia, Canberra.

Commonwealth of Australia 2009: The operation of the Environment Protection and Biodiversity Conservation Act 1999. Second and final report from the Inquiry into the operation of the Environment Protection and Biodiversity Conservation Act 1999. Commonwealth of Australia, Canberra.

Coppack, T. & Both, C. 2002: Predicting life-cycle adaptation of migratory birds to global climate change. *Ardea* **90**: 369–378.

Coppack, T., Pulido, F. & Berthold, P. 2001: Photoperiodic response to early hatching in a migratory bird species. *Oecologia* **128**: 181–186.

Cowie, J. 2007: *Climate Change: Biological and Human Aspects.* Cambridge University Press, Cambridge: 504 pp.

Cubit, S. 1996: *Recollections from the Forest. 75 years of Forest Service in Tasmania.* Forestry Tasmania, Hobart: 247 pp.

Datta, A. 1997: *John Gould in Australia:letters and drawings with a catalogue of manuscripts, correspondence and drawings relating to the birds and mammals of Australia held in The Natural History Museum, London.* Melbourne University Press and The Miegunyah Press, Carlton South.

DECCW 2009: Planning for catchment biodiversity targets at a local landscape scale: a proposal for the South-west Slopes Bioregion of NSW. NSW Government, Sydney.

Department of Environment and Water Resources 2007: EPBC Act - Environment Assessment Process. Australian Government, Canberra.

Department of Natural Resources 2006: Compliance under the Native Vegetation Act 2003. NSW Government, Sydney.

Department of Natural Resources and Environment 2002a: Government response to Environment Conservation Council Box-Ironbark Forests and Woodlands Investigation. Victorian Government, Melbourne.

Department of Natural Resources and Environment 2002b: Victoria's Native Vegetation Management - a Framework for Action. Victorian Government, Melbourne.

Department of Primary Industries Water and Environment 2000: Threatened Species Strategy for Tasmania. Tasmanian Government, Hobart.

Department of Sustainability and Environment 2003: Habitat Tree Prescriptions for Bendigo Forest Management Area. Victorian Government, Bendigo.

Department of Sustainability and Environment 2006a: Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978. Victorian Government, Melbourne.

Department of Sustainability and Environment 2006b: Native Vegetation – sustaining a living landscape. Victorian Government, Melbourne.

DPIPWE 2010: Vulnerability of Tasmania's Natural Environment to Climate Change: An Overview. Unpublished report. Department of Primary Industries, Parks, Water and Environment, Hobart.

Dunlop, M. & Brown, P.R. 2008: Implications of climate change for Australia's National Reserve System: A preliminary assessment. Report to the Department of Climate Change, February 2008. Canberra.

Dymock, W. 1870–1899: A new plan of the settlements in New South Wales: taken by order of Government. William Dymock, Sydney. National Library of Australia, Map 377 from Ferguson Collection Bib ID: 1853368, Canberra. Reprint. Originally published by John Booth 1810.

Ecologically Sustainable Development Steering Committee 1992: National Sustainable Development Strategy. Commonwealth of Australia, Canberra. http://www.environment.gov.au/about-us/esd/publications/national-esd-strategy.

EDO 2015: Review of the Forest Practices Code 2000. Environmental Defenders Office, Hobart. http://www.edotas.org.au/wp-content/uploads/2013/10/150515-Review-of-Forest-Practices-Code-EDO-Tasmania-submission.pdf.

EDO 2016: Our top 10 concerns with the draft Biodiversity Conservation Bill 2016 and Local Land Services Amendment Bill. http://www.edonsw.org.au/edo_nsw_top_10_concerns_with_draft_biodiversity_conservation_bill_2016_and_local_land_services_amendment_bill [Accessed 9 November 2015].

Environment Conservation Council 2001: Box-Ironbark Forests and Woodlands Investigation. Environment Conservation Council, Melbourne.

Environment Protection Authority 2007: Nature Assist - nature refuges incentives and assistance. http://www.ehp.qld.gov.au/ecosystems/nature-refuges/natureassist/ [Accessed 15 June 2016].

Felton, A., Fischer, J., Lindenmayer, D.B., Montague-Drake, R., Lowe, A.R., Saunders, D.L., Felton, A.M., Steffen, W., Munro, N.T., Youngentob, K., Gillen, J., Gibbons, P., Bruzgul, J.E., Fazey, I., Bond, S.J., Elliott, C.P., Macdonald, B.C.T., Porfirio, L.L., Westgate, M. & Worthy, M. 2009: Climate change, conservation and management: an assessment of the peer-reviewed scientific journal literature. *Biodiversity and Conservation* **18**: 2243–2253.

Flinn, J. 2006: Which way now? Glen Waverley, Victoria. Source: Debbie Saunders, private collection. Watercolour painting.

Forest Practices Authority 2015: Forest Practices Code. Forest Practices Authority, Hobart.

Forest Practices Board 2000: Forest Practices Board Annual Report 1999–00. Hobart.

Forest Practices Board 2001: Forest Practices Board Annual Report 2000–01. Hobart.

Forest Practices Board 2002: Forest Practices Board Annual Report 2001–02. Hobart.

Frawley, K. 1994: Evolving visions: environmental management and nature conservation in Australia. *In* Dovers, S (ed.): *Australian Environmental History.* Oxford University Press, Melbourne: 55–78.

Garnett, S., Franklin, D., Ehmke, G., VanDerWal, J., Hodgson, L., Pavey, C., Reside, A., Welbergen, J., Butchart, S., Perkins, G. & Williams, S. 2013: *Climate change adaptation strategies for Australian birds.* National Climate Change Adaptation Research Facility, Gold Coast: 925 pp.

Gibbons, P. & Boak, M. 2002: The value of paddock trees for regional conservation in an agricultural landscape. *Ecological Management and Restoration* **3**: 205–210.

Gill, S.T. 1855: Diggings at Little Bendigo, Forest Creek, 1852. James J. Blundell & Co., Melbourne. Source: National Library of Australia, Bib ID 438003, Canberra. Lithograph print. A plate from: The diggers & diggings of Victoria as they were in 1852. Pt. 1. S4014.

Gill, S.T. 1874: Diggings in the Mount Alexander district of Victoria in 1852. Source: National Library of Australia, Bib ID 3112373, Canberra. Watercolour painting on paper.

Google 2015: GoogleEarth with images from NASA DigitalGlobe

and TerraMetrics.

Gordo, O., Brotons, L., Ferrer, X. & Comas, P. 2005: Do changes in climate patterns in wintering areas affect the timing of the spring arrival of trans-Saharan migrant birds? *Global Change Biology* **11**: 12–21.

Gordo, O. & Sanz, J.J. 2008: The relative importance of conditions in wintering and passage areas on spring arrival dates: the case of long-distance Iberian migrants. *Journal of Ornithology* **149**: 199–210.

Gould, J. 1848: *Lathamus discolor* in *Eucalyptus gibbosus. Birds of Australia and Adjacent Islands* (Volume V). John Gould, London: pp. 101–103, Plate 47. (Source: National Library of Australia, Canberra).

Gould, J., Geoffroy Saint-Hilaire, E. & Mathews, G.M. :1848: *The Birds of Australia: and the Adjacent Islands.* (The author, London)

Gould, W.B. 1840s: Birds. Source: Art Gallery of Ballarat, Gift of Mr and Mrs Wallace White, 1980, Ballarat.

Gramenz, E. 2016: Critically endangered swift parrot breeding ground in Tasmania illegally logged for firewood. *ABC News, 30 July 2016* http://www.abc.net.au/news/2016-07-29/swift-parrot-habitat-illegaly-logged-for-firewood/7672504?section=tas

Grant, T.C. 1989: *History of foresty in New South Wales 1788 to 1988.* Star Printery, Erskinville.

Grinlinton, D. 1990: The Environmental Era and the Emergence of Environmental Law in Australia – a survey of Environmental Legislation and Litigation 1967–1987. *Environmental Planning and Law Journal (EPLJ)* **7**: 74.

Grose, M., Barnes-Keoghan, I., Corney, S., White, C., Holz, G., Bennett, J., Gaynor, S. & Bindoff, N. 2010: Climate Futures for Tasmania: general climate technical report. Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart.

Group, S.H. 2016: Generations Industrial Park EPBC Act Referral. Saunders Havill Group, Bowen Hills. http://epbcnotices.environment.gov.au/_entity/annotation/59d75e65-dc4f-e611-98e5-005056ba00a7/a71d58ad-4cba-48b6-8dab-f3091fc31cd5?t=1469681537978.

Halliday, K. 2005: Community Based Shire Wide Heritage Study Documents 2004-05. Liverpool Plains Shire Heritage Community Advisory Committee. Liverpool Plains Shire Council and NSW Heritage Office, Quirindi.

Heinsohn, R., Webb, M., Lacy, R., Terauds, A., Alderman, R. & Stojanovic, D. 2015: A severe predator-induced population decline predicted for endangered, migratory swift parrots (*Lathamus discolor*). *Biological Conservation* **186**: 75–82.

Hindwood, K.A. & Sharland, M. 1964: The swift parrot. *EMU* **63**: 310–326.

Hingston, A.B., Potts, B.M. & McQuillan, P.B. 2004: The swift parrot *Lathamus discolor* (Psittacidae), social bees (Apidae), and native insects as pollinators of *Eucalyptus globulus* ssp. *globulus* (Myrtaceae). *Australian Journal of Botany* **52**: 371–379.

Hoye, B., Klaassen, M. & Nolet, B.A. 2007: Ecophysiology of bird migration in the face of current global hazards: Climate change and avian flu. *Comparative Biochemistry and Physiology a-Molecular & Integrative Physiology* **148**: S128–S128.

Hughes, L. 2000: Biological consequences of global warming: is the signal already apparent? *Trends in Ecology & Evolution* **15**: 56–61.

Ingwersen, D. & Tzaros, C. 2011: Woodland Birds. *Wingspan* Winter: 22–25.

Innes, E.G. 1896: Reports of District Surveyors. Survey District of Franklin. In: 1896, Session II. Parliament of Tasmania, Department of Lands and Surveys: Report of Surveyor-General and Secretary for Lands for 1895. Parliamentary Paper No. 47. Appendix B. Government Printer, Hobart: 15–16.

IPCC 2014a: Climate Change 2014: Impacts, Adaptation and Vulnerability. Summary for Policymakers. Intergovernmental Panel on Climate Change No. Working Group II Contribution to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, Geneva.

IPCC 2014b: Regional Chapter 25, Australasia. *In* Climate Change 2014: Impacts, Adaptation and Vulnerability. (Intergovernmental Panel on Climate Change, Geneva)

IUCN 2015: IUCN Red List of Threatened Species. Version 2013.2. www.iucnredlist.org [Accessed 26 May 2016].

IUCN, UNEP, WWF 1980: World Conservation Strategy. Living resource conservation for sustainable development. International Union for the Conservation of Nature, Gland Switzerland.

Juniper, T. & Parr, M. 1998: *Parrots - A Guide to Parrots of the World.* Pica Press, Sussex.

Kennedy, S.J. & Overs, A.E. 2001: Foraging ecology and habitat use of the swift parrot on the south-western slopes of New South Wales. *Corella* **25**: 68–74.

Kirkpatrick, J.B. 1991: The magnitude and significance of land clearance in Tasmania in the 1980's. *Tasforests* December: 11–14.

Kirkpatrick, J.B.& Dickinson, K.J. 1982: Recent destruction of natural vegetation in Tasmania. *Search* **13**: 186–187.

Kirkpatrick, J.B. & Mendel, L. 1999: Native Vegetation Loss in Tasmania 1994–99. Unpublished report. University of Tasmania, Hobart.

Kuussaari, M., Bommarco, R., Heikkinen, R.K., Helm, A., Krauss, J., Lindborg, R., Öckinger, E., Pärtel, M., Pino, J., Rodà, F., Stefanescu, C., Teder, T., Zobel, M. & Steffan-Dewenter, I. 2009: Extinction debt: a challenge for biodiversity conservation. *Trends in Ecology & Evolution* **24**: 564–571.

Laubscher, C. 1999: *The Swift Parakeet. The Parrot Society UK Special Edition.* Principal Colour Ltd, U.K.

Law, B., Mackowski, C., Schoer, L. & Tweedie, T. 2000: Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales. *Austral Ecology* **25**: 160–178.

Lehikoinen, A., Kilpi, M. & Ost, M. 2006: Winter climate affects subsequent breeding success of common eiders. *Global Change Biology* **12**: 1355–1365.

Lehikoinen, E.S.A., Sparks, T.H., Zalakevicius, M.A. & Moller, W.Fa.P.B. 2004: Arrival and Departure Dates. *Advances in Ecological Research* **35**: 1–31. Academic Press, UK.

Low, T. 2008: Warming, invasive pests and birds. *In* Olsen, P. (ed.): *The State of Australia's Birds 2007. Birds in a changing climate.* Birds Australia, Melbourne: 18–19

Lunt, I.D. & Spooner, P.G. 2005: Using historical ecology to understand patterns of biodiversity in fragmented agricultural landscapes. *Journal of Biogeography* **32**: 1859–1873.

Macintosh, A. 2004: Why the Environment Protection and Biodiversity Conservation Act's referral, assessment and approval process is failing to achieve its environmental objectives. *Environmental Planning and Law Journal (EPLJ)* **21**: 288–311.

Macintosh, A. & Wilkinson, D. 2005: Environment Protection and Biodiversity Conservation Act: A five year assessment. Discussion Paper 81. The Australia Institute, Canberra.

Maron, M., Hobbs, R.J., Moilanen, A., Matthews, J.W., Christie, K., Gardner, T.A., Keith, D.A., Lindenmayer, D.B. & McAlpine, C.A. 2012: Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biological Conservation* **155**: 141–148.

Marshall, J. 2006: Brown v Forestry Tasmania Summary (No 4) FCA 1729, 19 December 2006. Federal Court of Australia, Hobart.[Accessed 14 August 2007].

Ministerial Review Committee 2006: Consolidated Report to the Ministers for Natural Resources and the Environment. NSW Native Vegetation Reforms. Ministerial Review

Committee, Canberra.

Moller, A.P., Berthold, P. & Fiedler, W. 2004: The challenge of future research on climate change and avian biology. *Advances in Ecological Research* **35**: 237–245. Academic Press, UK.

Munks, S., Richards, K., Meggs, J. & Brereton, R. 2004: The importance of adaptive management in 'off-reserve' conservation for forest fauna: implementing, monitoring and upgrading swift parrot *Lathamus discolor* conservation measures in Tasmania. In *In* Lunney, D. (ed.): *Conservation of Australia's Forest Fauna.* Royal Zoological Society, Mosman: 688–698.

Munro Hull, H. 1859: Hobart Town, from the tower of St. David's Church. Black and white picture. *In Experience of Forty Years in Tasmania.* Orger & Meryon, London and J. Walch and Sons, Hobart: 87. ADRI: AUTAS001126075480, State Library of Tasmania, Hobart.

Natural Resource Management Ministerial Council 2000: National Framework for the Management and Monitoring of Australia's Vegetation. Australian Government, Canberra.

Natural Resource Management Ministerial Council 2003: Framework for a national cooperative approach to Integrated Coastal Zone Management. Natural Resource Management Ministerial Council, Canberra.

Natural Resources and Water 2007: Vegetation management framework - fact sheet. The State of Queensland, Brisbane.

North, A.J. 1898: Birds of the County of Cumberland. *Handbook of the Australian Association for the Advancement of Science* 68–116.

NSW Department of Primary Industries 1999: Integrated Forest Operations Approval for Upper North East, Lower North East and Eden regions. Forestry and National Park Estate Act 1998. NSW Government, Sydney.

NSW Government 2013: Pacific Highway upgrade, Woolgoolga to Ballina. Biodiversity offset strategy, Swift Parrot. NSW Government, Sydney.

NSW Government 2014: Crown Lands Management Review. Chapter 4: Review of travelling stock reserves. NSW Government, Sydney.

NSW Local Land Services 2015: NSW Travelling Stock Reserves. Draft State Planning Framework 2016–19. NSW Government, Sydney.

NSW Office of Environment and Heritage 2013: Conservation agreements. http://www.environment.nsw.gov.au/cpp/ConservationAgreements.htm [Accessed 15 June 2016].

NSW Office of Environment and Heritage 2016: Saving Our Species partnerships grants - Round 2 project summaries. Australian National University. Saving our Swift Parrots and threatened woodland species. http://www.environment.nsw.gov.au/grants/2016-sos-summary.htm [Accessed 9 November 2015].

NSW Scientific Committee 1997: Cumberland Plain Woodland - endangered ecological community listing. http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations [Accessed 30 January 2016].

NSW Scientific Committee 2001: Native vegetation on cracking clay soils of the Liverpool Plains - endangered ecological community listing. http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations [Accessed 8 September 2015].

NSW Scientific Committee 2002: White Box, Yellow Box, Blakely's Red Gum Woodland - endangered ecological community listing. http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations [Accessed 30 January 2015].

NSW Scientific Committee 2004a: River-flat eucalypt forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions – endangered ecological community listing. http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations [Accessed 30 January 2015].

NSW Scientific Committee 2004b: Swamp sclerophyll forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions - endangered ecological community listing. http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations [Accessed 30 January 2015].

NSW Scientific Committee 2005: Lower Hunter Spotted Gum - Ironbark Forest in the Sydney Basin Bioregion – endangered ecological community listing. http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations [Accessed 30 January 2015].

NSW Scientific Committee 2006: Inland Grey Box Woodland in the Riverina, New South Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions - endangered ecological community preliminary listing. http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations [Accessed 9 November 2015].

O'Connor, T. 2016: Swift Parrot egg safe havens a 'bonanza' for endangered species. 7 October 2016. *ABC News* http://www.abc.net.au/news/2016-10-07/swift-parrot-eggs-found-in-experimental-nesting-boxes/7911138 [Accessed 9 November 2016].

Olsen, P. (ed.) 2007: *The State of Australia's Birds 2007. Birds in a changing climate.* Birds Australia, Melbourne.

Opdam, P. & Wascher, D. 2004: Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation* **117**: 285–297.

PAHSMA 2007: Port Arthur Historic Site. http://www.portarthur.org.au/index.aspx?id=12731 [Accessed 4 September 2015].

Parmesan, C. 2006: Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics* **37**: 637–669.

Parmesan, C. & Yohe, G. 2003: A globally coherent fingerprint of climate change impacts across natural systems. *Nature* **421**: 37–42.

Pimm, S.L. 2008: Biodiversity: Climate change or habitat loss – which will kill more species. *Current Biology* **18**: R117–R119.

Pollard, M 2000: Keeping swift parrots. http://www.finchsociety.org/cfa/parrot/swift/swift.htm [Accessed 18 July 2015].

Porfirio, L.L., Harris, R.M.B., Stojanovic, D., Webb, M.H. & Mackey, B. 2016: Projected direct and indirect effects of climate change on the Swift Parrot, an endangered migratory species. *EMU* **116**: 273–283.

Powell, J.M. 1969: The squatting occupation of Victoria, 1834–60. *Australian Geographical Studies* **7**: 9–27.

Pullinger, P. 2015: Pulling a swiftie. Systemic Tasmanian Government approval of logging known to damage swift parrot habitat. A report prepared for Environment Tasmania, Hobart.

Raper, G. c.1789: [Swift Parrot *Lathamus discolor*]. Attributed to George Raper (1769–1797). Source: National Treasures Collection of First Fleet Art, National Library of Australia, Canberra.

Resource Assessment Commission 1990: Australia's Forest and Timber Resources. Background paper No. 1. Resource Assessment Commission, Canberra.

Resource Planning and Development Commission 2003: State of the Environment Tasmania. Land Clearance Biodiversity Issues. Resource Planning and Development Commission (RPDC), Hobart. http://soer.justice.tas.gov.au/2003/bio/4/issue/41/ataglance.php.

Ribbentrop, B. 1896: Report on the state forests of Victoria. Government Printer, Melbourne.

Saunders, D.L. 2002: Assessment of swift parrot sites near Cessnock, lower hunter valley region, N.S.W. – including the Hunter Employment Zone. Independant unpublished report for the N.S.W. National Parks and Wildlife Service, Queanbeyan.

Saunders, D.L. 2008: Ecology and conservation of the swift parrot – an endangered austral migrant. Unpublished

PhD thesis, Australian National University.

Saunders, D.L. 2010: Review of NSW Forest Agreements and Integrated Forestry Operations Approvals. A submission to the NSW Department of Environment Climate Change and Water. Australian National University, Canberra.

Saunders, D.L., Brereton, R., Tzaros, C., Holdsworth, M. & Price, R. 2007: Conservation of the swift parrot *Lathamus discolor* - management lessons for a threatened migratory species. *Pacific Conservation Biology* **13**: 111–119.

Saunders, D.L., Cunningham, R., Wood, J. & Heinsohn, R. 2016: Responses of Critically Endangered migratory swift parrots to variable winter drought. *EMU* **http://dx.doi.org/10.1071/MU15126**, -.

Saunders, D.L. & Heinsohn, R. 2008: Winter habitat use by the endangered, migratory swift parrot (*Lathamus discolor*) in New South Wales, Australia. *EMU* **108**: 81–89.

Saunders, D.L. & Tzaros, C. 2011: National recovery plan for the swift parrot *Lathamus discolor*. Birds Australia, Melbourne.

State of NSW 2014: A review of biodiversity legislation in NSW. Final Report. Office of Environment and Heritage, Sydney. http://www.environment.nsw.gov.au/resources/biodiversity/BiodivLawReview.pdf.

Stojanovic, D., Terauds, A., Westgate, M.J., Webb, M.H., Roshier, D.A. & Heinsohn, R. 2015: Exploiting the richest patch has a fitness pay-off for the migratory swift parrot. *Journal of Animal Ecology* **84**: 1194–1201.

Stojanovic, D., Webb, M., Roshier, D., Saunders, D. & Heinsohn, R. 2012: Ground-based survey methods both overestimate and underestimate the abundance of suitable tree-cavities for the endangered swift parrot. *EMU* **112**: 350–356.

Stojanovic, D., Webb, M.H., Alderman, R., Porfirio, L.L. & Heinsohn, R. 2014: Discovery of a novel predator reveals extreme but highly variable mortality for an endangered migratory bird. *Diversity and Distributions* **20**: 1200–1207.

Tasmanian Government 2005: Tasmanian Community Forest Agreement. Commonwealth of Australia, Canberra.

Tasmanian Government 2009: Tasmanian Forest Conservation Fund. Commonwealth of Australia, Canberra.

Tasmanian Government 2015: Protected Areas on Private Land (PAPL). http://dpipwe.tas.gov.au/conservation/conservation-on-private-land/private-land-conservation-program/protected-areas-on-private-land [Accessed 15 June 2016].

Tasmanian Government 2016: Policy for maintaining a Permanent Native Forest Estate. Tasmanian Government, Hobart.

Tasmanian Lands Department 1917: Port Arthur 1844 F.P. Tasmanian Lands Department, Hobart. Source: Allport Library and Museum of Fine Arts and State Library of Tasmania, ADRI:AUTAS001124072174, Hobart. Print, photocopy on linen.

TSSC 2016: Conservation Advice Swift Parrot *Lathamus discolor,* established under the *Environment Protection and Biodiversity Conservation Act 1999*. Australian Government, Canberra, ACT.

Turner, J.W. 1996: Thematic history of Eurobodalla Shire. Hunter History Consultants, Newcastle. http://www.esc.nsw.gov.au/living-in/about/culture-and-heritage/heritage-studies/ThematicHistoryEShire.pdf.

Unknown Photographer 1877–: Bullock teams dragging logs to mill. Mill erected 1877. Cut timbers for local use including original Tarraganda Bridge. View looking west - Tanja via Bega, NSW. Mitchell Library, State Library of NSW, Sydney. Photograph, call number: At Work and Play - 02065.

Unknown Photographer 1880–1940: 7 ft high wheat crop on "Kia Ora", Grogan - Grogan, Temora area, NSW. Mitchell Library, State Library of NSW, Sydney. Photograph, call number: At Work and Play - 02881.

Victoria Parliament 1865: Report on the avisableness of establishing state forests. Parliamentary paper 77. The votes and proceedings of the legislative assembly 1864–5. Government Printer, Melbourne.

Victoria Parliament 1874: Papers relating to forest conservancy. Parliamentary paper 86. Legislative assembly papers presented to parliament. Government Printer, Melbourne.

Voogdt, J. 2006: Characteristics of swift parrot (*Lathamus discolor*) nesting habitat. Unpublished Honours thesis, Gerof-August-University of Gottingen.

Wadham, S. 1967: *Australian Farming 1788–1965*. F.W. Cheshire, Melbourne.

Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Hoegh-Guldberg, O. & Bairlein, F. 2002: Ecological responses to recent climate change. *Nature* **416**: 389–395.

Watling, T. 1793–1795: North-West View taken from the Rocks above Sydney Cove in New South Wales. Source: Natural History Museum, London. Watling Drawing no. 131.

Webb, M.H., Holdsworth, M.C. & Webb, J. 2012: Nesting requirements of the endangered swift parrot (*Lathamus discolor*). *EMU* **112**: 181–188.

Webb, M.H., Wotherspoon, S., Stojanovic, D., Heinsohn, R., Cunningham, R., Bell, P. & Terauds, A. 2014: Location matters: Using spatially explicit occupancy models to predict the distribution of the highly mobile, endangered swift parrot. *Biological Conservation* **176**: 99–108.

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Thesis:

Charleton, K.J. 2002: Variation in Sooty Shearwater burrow entrance density, burrow use and chick emergence: Science and Traditional Environmental Knowledge approaches. Unpublished MSc thesis, University of Otago, Dunedin.

Electronic version of journal:

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Website:

IUCN 2001: *IUCN Red List of Threatened Species 2001 Categories & Criteria (version 3.1)*, www.iucnredlist.org (accessed 22 January 2007).

Report:

MacKenzie, D.I. & Fletcher, D. 2005: Characterisation of seabird captures in NZ fisheries. Report to Ministry of Fisheries for Project ENV2004-04. April 2006. Unpublished Report to the Ministry of Fisheries, Wellington: 99 pp.

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